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THE SCIENTIFIC MONTHLY

FEBRUARY, 1931

THE ATLAS MOUNTAINS OF MOROCCO

By Professor ANDREW C. LAWSON

UNIVERSITY OF CALIFORNIA

THE accompanying map (Fig. 1) shows that Morocco extends over eight degrees of longitude and six of latitude. Its Atlantic coast stretches southwest from the Strait of Gibraltar for over 800 km. On the north it faces the Mediterranean for about 350 km. It adjoins Algeria on the east along a con-

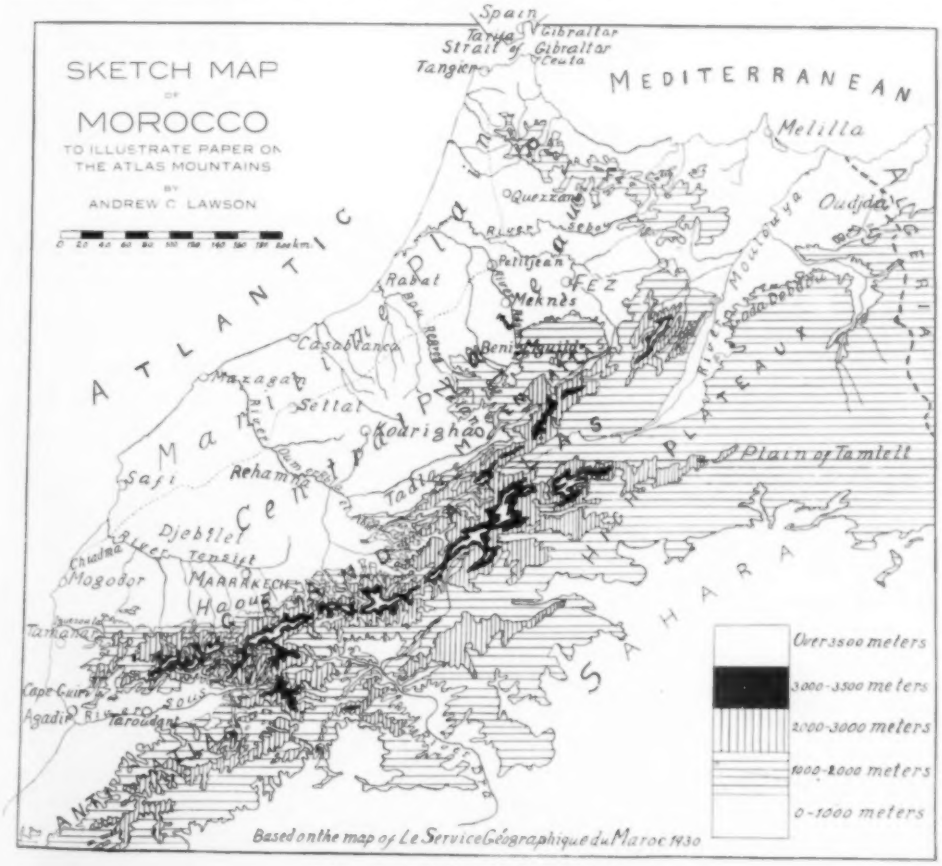

FIG. 1. MAP OF MOROCCO

SHOWING THE ATLAS BETWEEN THE CENTRAL PLATEAU AND THE HIGH PLATEAUX OF THE DESERT.

ventional boundary; but its limits on the south are indeterminate. Where Morocco ends and Sahara begins appears to be a matter of no political importance.

The Atlas Mountains, including in the system Beni Snassen, extend diagonally through Morocco from its southwest corner on the Atlantic to its northeast on the Mediterranean, the general trend being E.NE.; and they are flanked on both sides by plateaux and plains of diverse geomorphic character. The culminating peaks and ridges rise to altitudes of about 4,000 meters. In their descriptions of Morocco and on their maps of the country geographers have divided the Atlas into three ranges: (1) A central range known as the Grand or High Atlas; (2) the Moyen Atlas, lying to the northwest of the Grand Atlas in northern Morocco and separated from it only by the upper reaches of two opposed streams, the el Abid flowing southwest and the Moulouya flowing northeast; (3) the Anti Atlas, lying to the southeast of the south end of the Grand Atlas and separated from it only by the upper reaches of two opposed streams, the Sous and the Dra. The general trend of the Grand Atlas is slightly concave to the northwest, and the bearing of the range is a few degrees more nearly east-west than either the Moyen Atlas or the Anti Atlas.

The Rif Mountains in northern Morocco have a trend parallel to the concave Mediterranean coast, and appear on the map to be independent of the Atlas. They are an extension into Africa of the Bétie range of southern Spain. The structural ridges of the Bétie range curve around to a north-south trend in the vicinity of Gibraltar, and the formations which constitute them appear with the same trend on the south side of the strait, whence, curving easterly and then northeasterly in a mountain belt 250 km long, they pass out to sea in the vicinity of Melilla. The Rif is the Moroccan segment of a lobate range which is common to Europe and Africa. The Strait of Gibraltar and the submarine depression which determines it lie in the axis of the lobe. The north flank of the Rif is precipitate, while the south flank has a more gentle slope to the plateau which is traversed by the River Sebou, and which separates the Rif from the Moyen Atlas. This plateau, wide to the west and constricted to the east toward Taza, affords the only easy route for travel by land between western Morocco and Algeria. It has for that reason played a great rôle in the history of Morocco, and until recent years was politically and commercially the most important part of the country. The ancient capital cities of Fez and Meknès are situated on this plateau. To-day the most important commercial city is Casablanca on the Atlantic seaboard, and the chief political center is Rabat, also on the coast 87 km to the northeast, which is the seat of the French Residency.

The formations which enter into the make-up of the Atlas fall into two groups. The first of these comprises certain pre-Cambrian granites and schists of limited extent, a very large development of Cambrian quartzites, shales and limestones, and less extensive areas of Silurian, Devonian and Carboniferous strata. The rocks of this group were acutely deformed at the time of the Hercynian revolution and the resulting mountains, occupying a region very much more extensive than the present Atlas, were reduced to a peneplain. On this peneplain, and particularly in a geosyncline formed by the depression of a part of it, accumulated the formations of the second group. These comprise the continental deposits, fanglomerates, red beds, etc.,

of the Permo-Trias and the marine beds of the Jurassic, Cretaceous and Eocene. At the time of the Alpine Revolution this geosyncline collapsed, the rocks of both groups were more or less acutely folded, and a great mountain range took the place of the geosyncline. The thinner post-Carboniferous strata on the flanks of this Alpine uplift remained for the most part undisturbed, but there were areas of gentle folding, such as correspond to the foothills of a great range. The undisturbed strata and the flanking foothills stood much lower, horizon for horizon, than they do to-day. But, inasmuch as a thick prism of rock has been removed by erosion from these flanking regions since the Alpine Revolution, the surface of large parts of them may have been even higher than at present. Other parts were depressed in middle Tertiary time and, as in the region about Meknès and Fez, became embayments and straits of the Miocene sea.

The Atlas Mountains as we see them to-day are generally regarded as the product of the Alpine Revolution at the end of the Eocene. It is the purpose of this paper to show that while the structure of the Atlas, as displayed in its Mesozoic and early Tertiary formations, is properly referable to the Alpine earth movement, the region surrounding the range was reduced to a peneplain, and the range itself to residual hills, before the end of the Tertiary; and its present altitude and sculpture are due to the uplift of the region, including the hill range, by arching, and the upthrust of the latter by faulting.

From a geomorphic point of view the Atlas has the characteristics of a very youthful range. The canyons are narrow and V-shaped; and the crests are sharp ridges and peaks formed by the intersection of the canyon slopes. The streams have a torrential habit and flow in trenches far above the base-level of erosion. The general features are comparable to those of the southern half of the Sierra Nevada of California, the uplift and sculpture of which date from the end of the Tertiary, or to those of the post-Pliocene Himalaya. Many of the features of the Coast Ranges of California, a post-Pliocene uplift, are much more mature than those of the Atlas. It seems incredible to a geomorphologist that the youth and vigor of the Atlas could have survived from the time of the Alpine movement. He is at a loss to understand why they

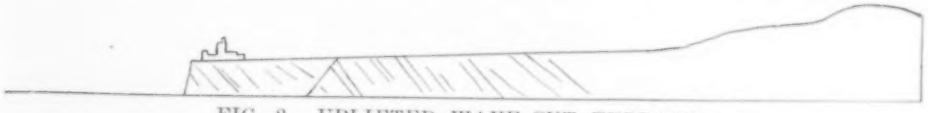

FIG. 2. UPLIFTED WAVE-CUT TERRACE
AT CAPE ST. VINCENT, PORTUGAL.

FIG. 3. UPLIFTED WAVE-CUT TERRACE
NEAR TARIFA, SPAIN.

FIG. 4. LOOKING FROM TANGIER TOWARD GIBRALTAR
SHOWING WAVE-CUT TERRACE 50 TO 65 M. HIGH.

FIG. 5. SEAWARD DIP
OF WAVE-WASHED TERTIARY SANDSTONE, AT RABAT.

should have endured so long, when the much more extensive Hercynian Mountains, formed in the late Carboniferous in the same region, were reduced to a peneplain in time to receive a veneer of continental deposits in the Permian. For a range of such antiquity he expects wide valleys and rounded past-mature divides, graded streams and gentle, soil-covered slopes. Finding instead of these the incisiveness of new dissection, steep rocky canyon walls and, in the Anti Atlas, remnants of an overarching peneplain which truncates the Alpine structures, he is forced to the hypothesis of geologically recent rejuvenation. The formulation of this hypothesis and the partial exploitation of the evidence which supports it are based on an all too scant acquaintance with the region obtained by three visits to Morocco, comprising: (1) a trip to Spanish Morocco in 1926 as a participant in an excursion organized by the International Geological Congress, meeting at Madrid that year; (2) various excursions in Morocco, Algeria and Tunis in 1928; and (3) an excursion into the Atlas in 1930 under the leadership of Messrs. L. Neltner and E. Roch. Very little has been written concerning the geology of Morocco; but I have had the advantage of reading M. Neltner's typewritten guide for the excursion of 1930, and a very excellent treatise on the geography of the country by Hardy and Célérier.[1] The maps which have been available to me are: Maroc, Carte dressée et publiée par le Service Geographique du Maroc. Echelle au 1,000,000. Rabat 1930; Carte geologique provisoire du Maroc par Louis Gentil. 1:1,500,000 Paris 1920; Croquis geologique de la zone française du Maroc, 1:3,500,000, issued to the excursionists of 1930.

Much of the evidence to which I refer consists of facts well known to Moroccan geologists, but the conclusion deduced from that evidence, as to the rejuvenation of the Atlas, is new.

The evidence of uplift of the region northwest of the Atlas is very plain although its extent may not be easily

[1] "Les grandes lignes de la géographie du Maroc," 2e Ed. Paris, 1927.

defined. At Cape St. Vincent in southern Portugal sea-cliffs extending on either side of the cape for more than twenty miles reveal the structure of the formations which here make up the coast. The strata are folded, in places acutely and in others more gently; occasionally a fault may be observed. The cliffs are from 50 to 65 m high, and back from their brink a level bench land extends for some miles. The surface of this bench is very clearly one of horizontal corrasion (see Fig. 2); and since the coast is here exposed to the full sweep of the Atlantic, there can be little doubt but that it is a wave-cut terrace, the analogue of that now being rapidly cut at the base of the present sea-cliffs. There are no deposits observable upon the abraded edges of the inclined strata at the bench level. There is no timber to obscure the view, and the terrace is covered with grassy vegetation. It rises very gently inland, and in the distance appears to have an altitude of perhaps 160 m. In side view from the southeast of the cape no steps are seen in the profile, and no well-defined sea-cliff could be made out at the back of the terrace, where it meets the hills. On the south side of the cape the terrace is dissected by a few sharp ravines which bring the drainage to the shore. It seems certain that this portion of the Iberian peninsula has been uplifted, and that the measure of the uplift is the height of the rear of the terrace above sea-level, ignoring fluctuations of the latter. The observation does not of course yield information as to the uniformity of the uplift or its extent.

The same physiographic evidence of uplift is observable on both sides of the Strait of Gibraltar, about 200 miles E.S.E. of Cape St. Vincent. On the Atlantic exposure of the north side of the strait in the vicinity of Tarifa a broad terrace slopes up very gently from the brink of the sea-cliffs to the hills, truncating inclined strata. The profile is shown in the sketch, Fig. 3.

Similarly on the south side of the strait, in the vicinity of Tangier, there is a fine wave-cut terrace extending for two or three miles along the coast at an altitude of between 50 to 65 m. The profile of this feature is well seen from Tangier from which the sketch in Fig. 4 was made.

From Tangier south to the junction

FIG. 6. THE MARITIME PLAIN

HERE A PENEPLAIN, LOOKING NORTH ACROSS THE RIVER BOU REGREG FROM RABAT.

FIG. 7. SETTAT
ON THE EDGE OF THE CENTRAL PLATEAU.

at Petitjean the railway crosses a well-defined, broadly dissected plain which slopes up eastward from the coast to elevations of over 65 m. This plain truncates folded Tertiary strata and is veneered locally with fluviatile gravels. It is traversed by six considerable streams flowing west to the Atlantic, five of them draining the western end of the Rif and the largest, the Sebou, draining by one of its branches the south flank of the Rif and by the other the north end of the Moyen Atlas. These streams in their lower reaches not only dissect the upland, but have evolved broad flood-plains along their courses. It appears probable that both wave and stream were concerned in the planation so apparent in this upland. Its present hypsometric position and its dissection prove the fact of uplift of at least 65 m. The full measure of uplift may be twice this.

The Tertiary sandstones underlying the plain are well exposed on the coast at Rabat as shown in Fig. 5. Here the seaward dip of the strata is much steeper than the slope of the plain. A fine view of the plain in profile from Rabat looking north across the river Bou Regreg is shown in the picture Fig. 6. There can be no doubt but that the surface shown here in profile truncates the strata of Fig. 5. The age of the strata is not known to the writer, but they are probably pre-Pliocene.

This stream dissected plain is the northern facies of the Maritime Plain which extends along the coast southwest of Rabat. The width of the Maritime Plain in the latitude of Petitjean is 75 km; at Settat it is 50 km and at Safi 25 km, beyond which it tapers out. It lies between the Central Plateau, which parallels the Atlas, and the Atlantic coast.

The feature of chief interest in the Maritime Plain is the veneer of marine Pliocene deposits which, with various interruptions and discontinuities, extends over its surface. The interruptions in the continuity of exposure of the Pliocene formations are due to: (1) High areas or inliers of the underlying basement from which the Pliocene beds have been removed by erosion, or upon which they were never deposited, as in the region between Rabat and the river Oum er Rbia; (2) Deltaic coverings of alluvium, as in the flood-plain of the

Sebou, and the ancient flood plain of a stream, now nearly defunct by capture, to the east of Safi; (3) ancient and modern sand dunes along the coast.

The inliers of the underlying basement consist chiefly of Paleozoic rocks with some rather notable and extended outcrops of the mantle of Permo-Trias red beds, which once covered the stumps of the Hercynian mountains throughout Morocco. Mesozoic marine rocks are generally absent from the basement upon which the Pliocene rests till we get as far south as Safi and as far west as Mazagan, at which points inliers of Cretaceous appear on the geological map.

South of Casablanca the Maritime Plain extends inland to the vicinity of Settat, where it ends at the base of a well-defined but maturely degraded scarp, which must have been the sea-cliff of the Pliocene sea. This ancient sea-cliff is here the northern limit of the Central Plateau, the drainage from which has indented the scarp with gullies and ravines. These do not, however, extend very far back in to the plateau, and in their upper reaches the streams flow in shallow trenches on its surface.

Near its outer edge, east of Settat (Fig. 7), the Central Plateau has an altitude of about 500 meters, and its precipitous front is about 200 meters high, rising abruptly from the plain. The Pliocene sea floor at the base of the ancient sea-cliff is thus about 300 meters above sea-level and this is a fair measure of the local uplift in post-Tertiary time. The uplift was by no means uniform, however, and it probably increases in amount toward the mountains, since Neltner[2] states that the marine Pliocene occurs at elevations of 500 meters.

The uplift indicated by these elevated Pliocene deposits was not limited to the close of the Tertiary. It has been a gradual movement and is still in progress. Beyond the southern limit of the Maritime Plain between Mogodor and Agadir, where the Grand Atlas extends to the coast, there are recent wave-cut terraces. At Cape Guir, where the Cretaceous strata are steeply inclined, there is a terrace 200 to 300 m wide, which, at the base of its complementary sea-cliff, still undegraded, has an elevation of about 50 meters. Above this there is a narrow terrace at about 65 meters; and below there is another at about 25 meters. The present sea-cliff is in active recession, and the mere existence of these elevated strands on a bold coast, exposed to the rapid corrasion of the open Atlantic, is ample proof of the recency of the uplift.

Away above the terraces just referred to there is a much older one at about

[2] MS. text of guide for geological excursion of 1930.

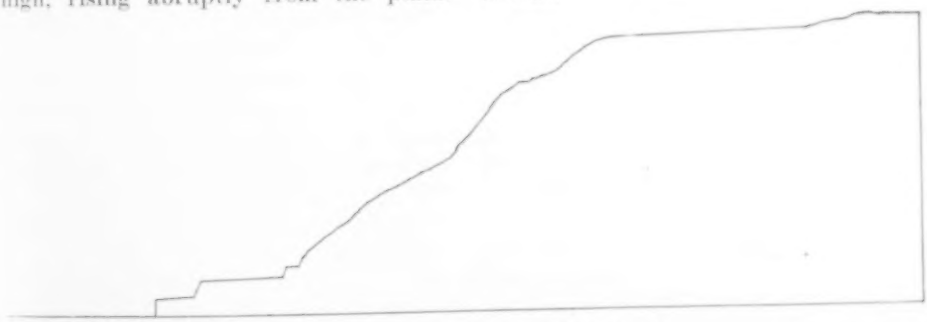

FIG. 8. PROFILE AT CAPE GUIR

SHOWING WAVE-CUT TERRACES.

380 meters truncating strata which dip south at angles of from 20° to 30°. This high terrace appears as a trench which has been cut in the seaward slope of a peneplain that extends over this end of the Atlas, and attains an altitude of over 700 meters. A sketch of an east-west profile through Cape Guir showing these features is given in Fig. 8.

In the valley of the Iguezoula north of Tamanar there is a fine display of wide stream terraces corresponding to the 50-meter marine terrace at Cape Guir. Below this is a narrow terrace at about 25 meters above the stream. Looking up this valley from a commanding point the upper terrace is seen to be a very extensive, wide valley floor ending in a gap in the skyline profile of a high dominating peneplain. The stream has a sinuous course through the old valley land. Since the terrace was the functional valley floor uplift has caused its dissection, and the present narrow stream gorge proclaims in eloquent terms its extreme youth.

On the way from Mogodor to Safi the road parallels the coast about 15 km inland. At about one third of the distance it climbs to a flat divide on the surface of a peneplain, and then descends to the valley of the river Tensift. The peneplain truncates folded rocks and is maturely dissected in its higher parts. A large area of it to the west of the road overlooks the sea, and the short streams in their lower reaches flow in sharp gorges. The general elevation of the surface near the coast is about 500 m. Toward the south it rises to over 1,000 m and extends over the western end of the Atlas. It is probably a warped surface.

This upland, which may be conveniently called the Chiadma peneplain, is bounded on the north by the broad east-west valley of the Tensift, which drains the Grand Atlas south and east of Marrakech. On the north side of that valley the correlative of the Chiadma peneplain is the Central Plateau to which reference has already been made. This is a steppe land, with a dry steppe climate, thinly populated and more adapted for grazing than for tillage, and so presents a striking contrast to the fertile, more humid Maritime Plain. It lies between the Maritime Plain and the Atlas, but is separated from the mountains in its southern part by extended depressions at the base of the latter, in which are deployed the flood plains of the middle reaches of the Tensift and the Oum er Rbia. The Central Plateau extends northeast from the valley of the Tensift to the southern flanks of the Rif, where it is traversed by the Sebou River. In its northern part the distinction between the plateau and the Moyen Atlas is not easy since the surface of the former slopes up toward the mountains and extends over their flanks.

The rocks underlying the surface of the Central Plateau vary greatly in different parts of it; but they fall into three groups: (1) The greatly disturbed and altered Paleozoic rocks that make up the stumps of the Hercynian mountains; (2) the little disturbed Mesozoic and Eocene strata that lie nearly flat on the post-Hercynian peneplain, undeformed by the Alpine movement; (3) the Miocene deposits of the Meknès basin. The portions of the plateau best known to the writer are those traversed by the road from Casablanca to Marrakech, the phosphate mining district around Kourigha, and the region between Meknès and Taza. The higher parts of the plateau about the mines at Kourigha are occupied by an Eocene formation containing beds of phosphate of lime. These lie in nearly flat attitudes upon the Cretaceous formations, which in turn are seen at a number of places to rest upon the Permo-Trias, while the latter reposes upon the post-Hercynian peneplain. The Eocene of

FIG. 9. THE CENTRAL PLATEAU EAST OF MEKNÈS
LOOKING SOUTH TOWARD BENI MGUILD.

Kourigha is a residual patch of a once much more extensive and thicker formation. A similar residual patch occupies much of the territory between Rehamna and Djebilet; and there are others to the south of the Tensift. The Cretaceous is a larger remnant. It once extended over much if not the whole of the areas in which the Paleozoic rocks now appear at the surface. These areas are essentially the exhumed post-Hercynian peneplain, although of course the old surface has been modified somewhat since the Mesozoic cover was stripped away. Three areas of the post-Hercynian peneplain diversify the Central Plateau. They occupy a large part of the districts known as Zaïan in the latitude of Casablanca, Rehamna south of the river Oum er Rbia and Djebilet north of the Tensift. It is evident from the relief of the Rehamna where it emerges from below the Cretaceous that it was rather an uneven surface upon which the Mesozoic rocks were deposited, since some of the hills of Paleozoic rocks rise well above the present surface of the Cretaceous.

The removal of the greater part of the Eocene and the exhumation of the old pre-Permian surface has produced a post-Alpine peneplain which in part happens to almost coincide with the post-Hercynian one. The fact that this post-Alpine peneplain is so near the sea indicates that it was evolved close to the base-level of land erosion. The incisive sharpness of the inner gorge of the Oum er Rbia, which transects it, testifies to the recency of its uplift. The way in which the river traverses this high inlier of old hard rocks, in the midst of the flat lying residual Cretaceous, testifies also to the fact that it is a superimposed stream, the course of which was determined by the slope of the plateau when it was covered by higher Cretaceous or Eocene strata now removed. The uplift must, however, have had at least two stages. At the time of the emergence of the Pliocene sea floor, or the Maritime Plain, it was elevated through a minimum of 300 m. It is doubtless this stage which finds its expression in the sharpness of the lower stream gorges. But when the scarp at Settat was a functional sea-cliff, the plateau at its seaward margin already had an altitude of 200 m. The geological date of this early stage of uplift was probably

FIG. 10. THE CITY OF FEZ

at the end of the Miocene, since the Miocene formations at the north end of the Central Plateau, in the Meknès basin, have no covering of marine Pliocene at the plateau level.

At Petitjean the railway leaves the Maritime Plain at an altitude of about 250 m and climbs south through the gorge of the river Rdom to the high plain on which Meknès is situated. At Meknès this surface has an altitude of about 500 m, but it rises very gently to the south through another 500 m, and then steps up 100 m by a degraded scarp to the limestone plateau of Beni Mguild (see Fig. 9). The latter in turn by steepening slopes grades into the sides of the Moyen Atlas. The rocks underlying the Meknès-Fez plain are partly soft marine Tertiary beds and partly lake beds. The plain extends eastward through the pass of Taza without important change of level to the valley of the Moulouya. It is a surface of erosion evolved at low levels, and now dissected by streams as a result of uplift. Between Fez (Fig. 10) and Taza the most important route of travel in Morocco passes between the Rif and the Moyen Atlas through a broadly terraced valley, narrowing eastward. Beyond Taza the country opens out upon a broad desert traversed by the terraced canyons of the Moulouya and its tributaries. The flat surface of the desert is an uplifted flood plain of the river, and to the south one gets distant views of a still higher peneplain, as shown in Fig. 11, a picture of the country looking southeast from the hotel at Taza.

The Meknès basin including its extension eastward through the pass of Taza, is superficially distinct from the rest of the Central Plateau by the difference in its underlying formations, and by the fact that a monadnock of the old Hercynian peneplain in the Zaïan seems to break the continuity of the plateau surface. But since it has the same general altitude as the country southeast of the monadnock, and is an erosional surface which acquired that altitude by uplift in the same way and at the same times as the Central Plateau, it may properly be regarded morphologically as part of the latter.

The physiographic evidence of post-Tertiary uplift is not confined to the northwest side of the Atlas. The uplifted, dissected and terraced flood plain of the Moulouya not only extends north to the Mediterranean through the Tell, a region of small isolated mountains of folded Mesozoic strata, but up stream it extends through high plateaux into the acute reëntrant between the Moyen Atlas and the north end of the Grand Atlas. The plateaux of Jurassic and Cretaceous strata which enclose it slope up to the Moyen Atlas on one side and to the Grand Atlas on the other in a synclinal disposition. In this syncline the latest geological map[3] shows a basin of Miocene formations at altitudes of over 1,000 m. This basin of soft Miocene beds, lying in a broad syncline of harder rocks, has determined the widening of the flood plain of the river above its constriction at the northeast end of the Moyen Atlas.

Concerning the vast plateaux at altitudes of over 1,000 m, which lie on the continental side of the Atlas, extending east into Algeria and south toward, if not into the Sahara, we have but meager information. The high Plain of Tamlelt, which at an altitude of nearly 2,000 m divides the drainage to the Mediterranean from that into the Saraha, appears to be a broad structural arch feebly folded and broken along its axis. The axial region is shown on the geological map to be occupied by Lias and Jurassic formations, while the extensive nearly flat slopes to the north and to the south are Cretaceous. At the foot of the

[3] Scale, 1:3,500,000 issued without date to participants in the geological excursion of 1930.

FIG. 10. THE CITY OF FEZ

FIG. 11. A VIEW SOUTHEAST FROM TAZA
SHOWING A HIGH PENEPLAIN.

northern slope the Cretaceous lies again upon the Jurassic in the Gada Debdou, which presents an escarpment to the ancient flood plain of the Moulouya. The shallow Cretaceous syncline thus located in the middle slope is the same as that in which the basin of Miocene lies in the upper Moulouya. The anticlinal arch of Tamlelt serves to establish orogenic continuity between the Grand Atlas and the ranges of southern Algeria. Since the folding, however broad and gentle, which gave rise to this connecting geanticline is pre-Miocene in age, it may safely be regarded as a product of the Alpine movement. The surface of the plateau, which thus stretches from Gada Debdou to Tamlelt and from the end of the Grand Atlas into Algeria, is a surface of erosion which truncates indifferently the various formations of the Lias, Jurassic and Cretaceous. It is therefore a very perfect peneplain which has recently been uplifted; since, being so near the Mediterranean, it could not have been formed at the present altitude. It is now in the initial stages of dissection by vertical corrasion. Had the uplift been of ancient date, in a geological sense, the dissection would have been far advanced; and the plateau, if it still retained its altitude, would do so only as an aggregate of buttes and mesas.

The Anti Atlas is separated from the south end of the Grand Atlas by the valley of the river Sous (Fig. 12) and connected with it by the high but much degraded volcanic pile of Sirwa about 200 km east of Agadir. It consists of folded Mesozoic strata resting unconformably upon more intensely deformed Paleozoic rocks, and appears to have had the same orogenic history as the Grand Atlas. On the road between Taroudant on the Sous River and Igherm, a military and administrative post on the south side of the crest, excellent views are obtained of the rocks, the tectonic features and the geomorphy of the range. The most notable feature observed, from the point of view of the present discussion, is an extensive peneplain, remnants of which extend well over the Anti Atlas. The wide-spread truncation of the folded Mesozoic strata is surprisingly clear on the northern flank of the range, where it is seen to slope down toward the valley of the Sous; and it appears that the dislocation

of this peneplain by faulting along the southern flank of the Grand Atlas is the most probable origin of the valley of the Sous. The attitude of the peneplain on the south flank of the Anti Atlas is unknown, but it seems probable that this interesting feature arches over the range and slopes down to the Sahara.

From the foregoing observations we may conclude that the Anti Atlas of Oligocene time was reduced by the prolonged erosion of the later Tertiary to a surface of low relief, which traversed indifferently both its Alpine and its Hercynian structures, and that the range as we know it to-day is the result of the uplift of that surface, probably in the form of an arch, and the sculpture by erosion of the uplifted mass.

In general the various plateaux which surround the Atlas Mountains, and in part extend over them, are remnants of an extensive peneplain of post-Alpine origin which has been uplifted by arching, and in part dislocated by faulting, in late Tertiary and Quaternary time. The maximum uplift of these plateaux is at the margin of the mountains or, in the case of the Anti Atlas, along the axis of the range. In the Moyen Atlas they extend well up on the flanks of the range to levels above which they have been obliterated by erosion; in the Grand Atlas the projection of their surfaces abuts upon the very steep mountain fronts, where large faults dominate the geomorphic features. The most notable of these marginal fault zones is that which limits the Grand Atlas along the front overlooking the Haouz of Marrakech, a structural trough formed by the sinking of a broad belt of the Central Plateau along the northern border of the range. Here the mountains rise abruptly from the lowland of the Haouz in what appears from a distance to be a

FIG. 12. THE RIVER SOUS

BETWEEN THE GRAND ATLAS AND THE ANTI ATLAS.

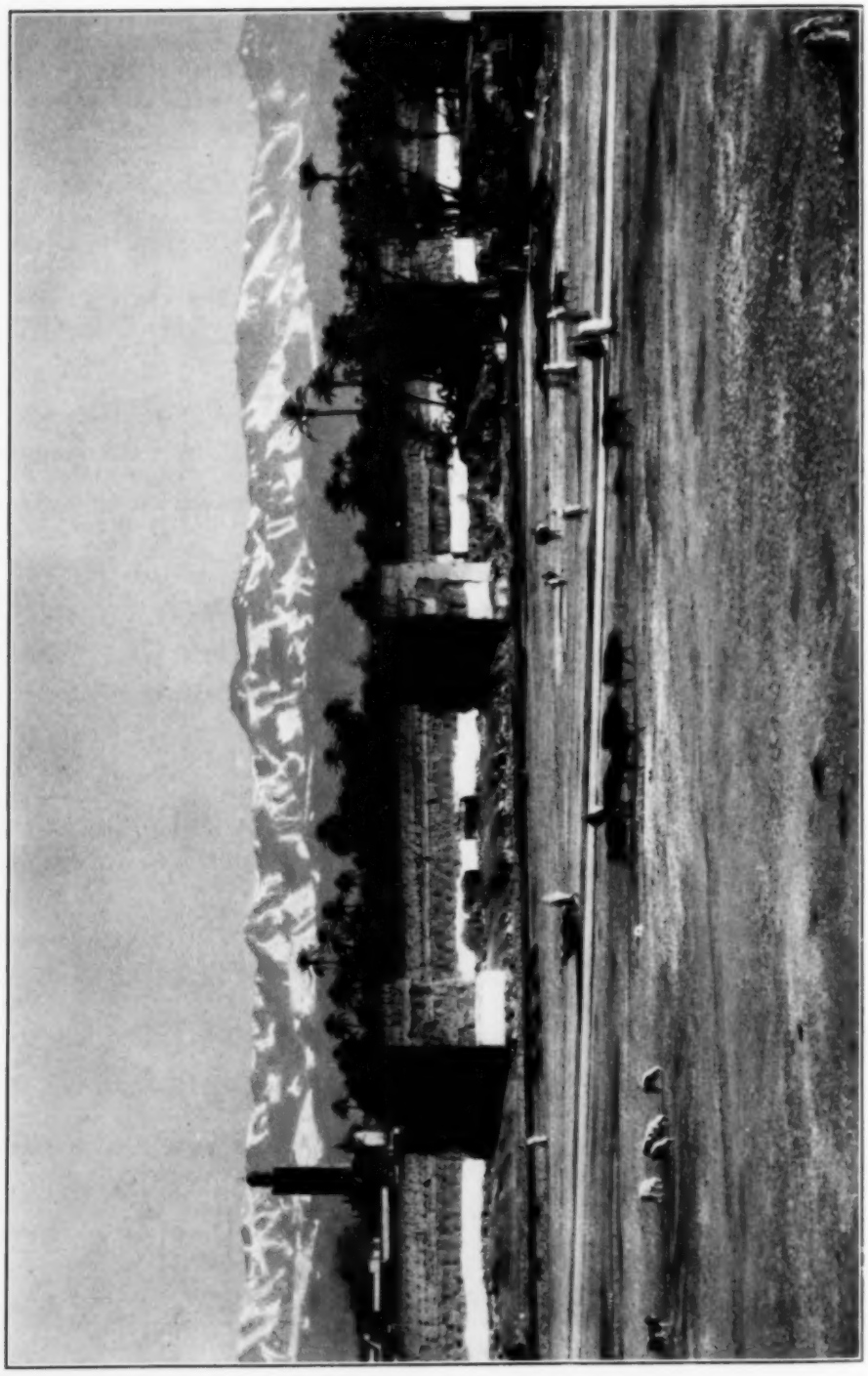

FIG. 13. THE GRAND ATLAS

great wall as shown in the pictures, Figs. 13 and 14. The effect is not unlike that of the eastern front of the Sierra Nevada of California, and geologists are agreed that it is due to a great dislocation of the earth's crust. Just within the mountain front on the road from Marrakech to Azni several minor faults of the zone may be seen at close quarters. They are steep normal faults with downthrow to the north, and the drag in the thinly stratified rocks is well displayed on the side of the canyon.

The Haouz is filled with fluviatile detritus (see Fig. 15), the depth of which is not apparent, and the surface of the fill is now the flood plain of the Tensift and its numerous torrential tributaries. A similar depression, known as the Tadla, lies at the base of the south end of the Moyen Atlas, and although the mountain slope is here much more subdued, a zone of faulting is mapped by Gentil[4] at the base of the range northeast of Kenifra, which suggests that the front of the Moyen Atlas may also be defined by a fault, analogous to that of the Grand Atlas. Gentil's fault zone if prolonged would not only drop the south border of the Central Plateau against the Moyen Atlas, but would serve also as the southern boundary of the depression to the north of the Djebilet, which is the westward extension of the Tadla. That the combined depression of the Haouz and Tadla is structurally double appears from the fact that the continuity of the two is offset to correspond with the reëntrant between the south end of the Moyen Atlas and the Grand Atlas.

The peneplain of the Central Plateau once extended to the present front of the Atlas across the existing troughs of the Haouz and the Tadla before the depression was inaugurated (see Fig. 16), just as it still does on the south side of the Tensift near the coast, and north of the Tadla. The projection of its surface over those depressions would intersect the steep profile of the Atlas at an altitude of about 1,200 m. Before the uplift of the peneplain we may suppose that in late Tertiary time the Atlas of Alpine origin had been reduced to a residual hill range of past-mature slopes, having an altitude of perhaps 600 m. The effect of the uplift of the region in a great arch, affecting both peneplain and hills, would be to elevate the latter through about 1,400 m, giving them an altitude of about 2,000 m and subjecting them to vigorous vertical corrasion.

It is convenient in analysis to think of the general arching of the region as having preceded the more local and intensive upthrust to which the present configuration of the Atlas is primarily due. But, as will appear in the sequel, the arching may have been synchronous with the orogenic upthrust, and indeed due to it. However that may be, it is clear that the two movements, general or epeirogenic arching and local or orogenic upthrust, were involved in the rejuvenation of the range. From the preceding cycle, in which the Alpine Atlas was reduced to residual hills, it is certain that the new range would have inherited a shear stress on both flanks. As a relief from this stress marginal faults had long since been developed and it was between these that the upthrust, due to orogenic forces of compression, was localized. The rapid degradation of the upthrust mass and its consequent loss of load, would induce a still farther rise of the range, and this rise is still going on It is this supplementary rise due to isostatic adjustment, which, by causing a withdrawal of heavy rock in depths from the flanking regions, explains the origin of such depressions as the Haouz of Marrakech, the Tadla and the Sous. The evidence of the latest phase of this movement consists of a system of stream terraces which are ob-

[4] Carte géologique provisoire du Maroc, 1920.

FIG. 13. THE GRAND ATLAS
LOOKING ACROSS THE HAOUZ OF MARRAKECH

FIG. 14. THE GRAND ATLAS
LOOKING OVER THE CITY OF MARRAKECH.

FIG. 15. THE ALLUVIAL PLAIN
OF THE HAOUZ OF MARRAKECH.

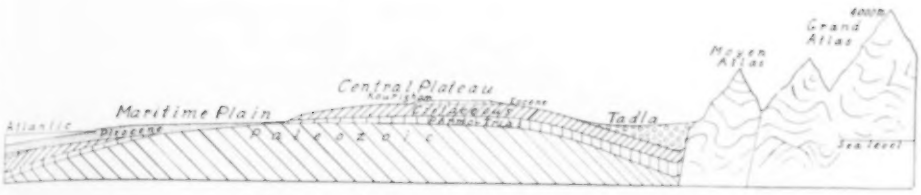

FIG. 16. HYPOTHETICAL SECTION
ACROSS THE MARITIME PLAIN, THE CENTRAL PLATEAU, THE TADLA, AND THE ATLAS.

servable in many of the great canyons at altitudes of from 65 m to 85 m above the streams, and in terraces at the front of the range which appear to be uplifted portions of the flood plains of the streams now dissecting them, as exemplified at the mouth of the canyon followed by the road from Marrakech to Azni (Fig. 17).

The doctrine of isostasy in its extreme form teaches that the Atlas is the top of a column of the earth's crust which is in balance with other neighboring columns the tops of which are much nearer sea-level or, indeed, below it. The areal limits within which the principle of isostasy applies is, however, as yet uncertain owing to the fact that the rigidity of the crust interferes with its operation, the measure of that rigidity being unknown. It is desirable, however, in any discussion of the genesis of a great mountain range to at least consider the possible rôle played by isostasy in its historical development and in its reduction under erosion. The remarkable depressions of the Haouz and Tadla on the north side of the Grand Atlas, and that of the valley of the Sous on the south side, are suggestive of a transfer of mass in depth from the sides of the range to its base, to compensate for its loss of load by erosion; and a brief discussion of this possibility may be of interest. For the sake of clearness in treatment I shall assume the validity of isostasy as applied to the Atlas and present the considerations involved rather dogmatically.

I shall begin by stating again that the Atlas as we know it to-day is due to the operation of a late Tertiary or post-Tertiary collapse of the earth's crust under excessive compressive stress. This stress was not isostatic, but the concentration of mass which gave rise to the range proceeded under the control of isostasy. That is to say, while the crowding together of the rocks of the sial tended to disturb the balance, that tendency was never very effective owing to the fact that the upthrust, due to horizontal compression, was compensated by a much larger downthrust into the sima below the growing range. In this way the range maintained its buoyancy, and the total mass of the column from the summit, at all stages of its

FIG. 17. STREAM TERRACE
AT THE FRONT OF THE GRAND ATLAS ON THE ROAD FROM MARRAKECH TO AZNI.

genesis, down to the zone of compensation remained constant and in balance with neighboring columns not directly affected by the collapse. If the sial be supposed to be 20 km thick from sea-level down, with a mean specific gravity of 2.7, and to rest upon a layer of sima 20 km thick with a specific gravity of 3, then for every kilometer of upthrust there would be 9 kilometers of downthrust into the sima. The mountains are thus a prism of sial floating in sima, just as ice floats in water, except for the great difference in viscosity. If the orogenic upthrust had been say 1 km in the Grand Atlas, then the downthrust of the same light rocks into the sima would have been 9 km. If the width of the Atlas be taken at 50 km, then a prism of sima 50 x 9 km in cross-section was displaced by this downthrust. The greater part of this prism, distributed by rock flow into the adjoining regions, would have caused an uplift or flat arching of the earth's crust. If such an arch had a maximum uplift of 1 km at the mountains it would have extended out on either side of them for a distance of 400 km, there tapering out to nothing. This redistribution of sima from below the Atlas, at the time of the upthrust about the end of the Tertiary, may well have been the cause of the arching of the peneplain surrounding the residual Alpine Atlas. In the discussion that arching was separated for convenience from the upthrust but the two movements may have been intimately connected genetically. The added load due to the redistribution of the displaced sima would of course have tended to disturb the balance of the earth as a whole, and would have necessitated an isostatic adjustment of the entire spheroid.

As the upthrust proceeded the Atlas would loose load by erosion, but we may consider the effect of this erosion more conveniently by thinking of the orogenic upthrust having been completed before erosion began its work of degradation. The upthrust was effectively a dislocation of the residual hills of the Alpine Atlas from the adjoining peneplain and a rejuvenation of the old worn-down mountains. If we reduce the hills, as they may be pictured after arching and before upthrust, to a uniformly level surface, they would have had an altitude of about 1,600 m. Let p be the amount of vertical upthrust, then $1{,}600 + p$ would be the value for the effective height of the Atlas before erosion, or the height at which the range would now stand if there had been no degradation. The mean crest line of the Atlas to-day is about 3,800 m, and the mean stream level is about 1,000 m above sea-level. Since the canyons are V-shaped and the crests are generally sharp, due to intersection of canyon walls, $1{,}000 + \frac{3{,}800 - 1{,}000}{2} = 2{,}400$ m is the height of a level topped prism equal to the present mass of the Atlas above sea-level. The loss of height as a result of erosion of the upthrust column is thus $1{,}600 + p - 2{,}400$ or $p - 800$ m. But there is a simple relation between the loss of height and the thickness of the effective prism removed. For every 1 removed there is a rise of the column of 2.7/3 or 9/10 and a loss of height of 1/10. Therefore the effective prism removed is $10(p - 800)$ m. In the case of the Atlas there are no observational data from which the value of p may be derived. But it may be of interest to examine the consequences of an assumed value. Suppose, for example, that p were 1,000 m. Then the loss of height $p - 800$ would be 200 m. and the rise of the column, $9(p - 800)$, would be 1,800 m. The rise of the column is effected by an inflow of sima from the adjoining regions to the bottom of the column. The prism of sima thus inserted is 1,800 m thick. Half

of this came from under the Haouz and half from the south side of the Atlas. Considering the Haouz of the same width as the Atlas a prism effectively 900 meters thick for that width was withdrawn from under it. But the prism was probably wedge-shaped in cross-section, tapering out to nothing on the far side of the Haouz. At the border of the mountain column therefore it had a thickness of 1,800 m. The downthrow of the peneplain to form the depression of the Haouz was thus 1,800 m, and the alluvial deposit which occupies the depression has a thickness of 1,200 meters near the mountains where its top is 600 m above sea-level.

But small changes in the assumed value of the orogenic upthrust make large differences in these results. Thus if we make $p = 900$ m instead of 1,000 m, then the loss of height for the effective level-topped prism becomes 100 m, the effective prism removed 1,000 m, the rise of the column 900 m, the downthrow on the north side of the mountains 900 m and the thickness of the alluvium on the south side of the Haouz 300 m.

Owing to the uncertainty of the assumptions made the figures have little value except that they illuminate the geological implications of the doctrine of isostasy as applied to great mountain ranges. If the thickness of the alluvium in the Haouz were known as the result of boring operations near the border of the mountains the value of p would also be determined. Similarly, if a geomorphologist should some day discover on the crest of the Grand Atlas remnants of the uplifted worn-down surface of the residual Alpine Atlas, corresponding to the remnants of the peneplain so apparent on the summits of the Anti Atlas, then the value of p would be 940 m, the rise of the column under erosion would be 1,260 m and the thickness of the alluvium on the south side of the Haouz 660 m.

Summary

The Hercynian mountains, extending over a very much larger region than the Atlas, were reduced to a peneplain upon which were spread the continental fanglomerates, red beds, etc., of the Permo-Trias. In a geosynclinal depression of this veneered peneplain there were deposited great thicknesses of Liassic, Jurassic, Cretaceous and Eocene marine formations. At the time of the Alpine Revolution, about the end of the Eocene, the collapse of this geosyncline by compressive stress gave rise to the Alpine Atlas. By the end of the Tertiary the latter had been reduced to a past-mature hill range and the surrounding country to a peneplain. The rejuvenation of this hill land into the present Atlas is due to two distinct movements: A broad arching in at least two stages which lifted the peneplain near the mountains to about 1,200 m above sea-level; and a sharp orogenic upthrust, between marginal faults inherited from the preceding cycle. The degradation of the upthrust mass and consequent loss of load induced farther rise by isostatic adjustment. The depressions flanking the range are explained as due to withdrawal of material in depth to compensate the range for its loss of load.

Antonj van Leeuwenhoek

ON THE TRAIL OF VAN LEEUWENHOEK

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THE father of microscopy, Antony van Leeuwenhoek, the son of Philip van Leeuwenhoek and Margaretha Bel van den Bergh, born at Delft, October 24, 1632, was a pioneer in biology, and through him new sciences saw the day. Van Leeuwenhoek was descended from a family of brewers. His father having died during his childhood, he was sent by his mother to the village school at Warmond, where he obtained his early education. Later he went to Benthuizen with the intention of preparing for a position in the municipal government of that city, his uncle being the secretary of the administration. At sixteen he was apprenticed to a draper at Amsterdam, whose cashier and bookkeeper he soon became, and here it was he learned to use the magnifying glass which drapers then employed for counting the threads in their goods. It is highly probable that this led him to study optical instruments and to make the microscopes and the great discoveries which made him famous. After spending some years in the drapery business he returned to Delft and married Barbara de Mey, on July 26, 1654. Five children were the result of this union; a daughter, Maria, survived him. His wife died twelve years after this marriage. His second wife was Cornelia Swalmius. The issue of this marriage was a girl who died early in life. At Delft he became "Kamerbewaarder der Kamer van Heeren Schepenen van Delft," a position neither ardouous nor exacting, which he held for thirty-nine years and which enabled him to devote a great part of his time to work of his own selection.[1]

Van Leeuwenhoek's house still exists at Delft, says Haaxman. It is No. 455, on the corner of Botersteeg and Oude Delft, Wijk 4. The façade is changed, but the side and rear of the house remain unaltered.[1]

"In the year 1673," Quekett tells us, "the name of the immortal Van Leeuwenhoek first appears in the *Philosophical Transactions* of this country [England], as a discoverer of numerous wonders by the aid of the microscope; his instruments, which were composed of single lenses, are said to have been superior to all that had been previously made."[2]

Van Leeuwenhoek constructed his microscopes and lenses, and asserted the latter must be of exceptionally fine rock crystal. The essentials in which his microscopes surpassed all others were in his knowledge of grinding, polishing and mounting the lenses, so that no one could compete with him. His microscopes were mechanically rough and were made especially for the examination of one, two or three objects. Most of his lenses had a quarter-inch focus and were mounted between two thin plates either of copper or silver-bronze or silver or gold. The magnifying power of his microscopes varied apparently between forty and two hundred and seventy diameters. The museum at Utrecht contains, says Harting, a microscope made by Van Leeuwenhoek which magnifies two hundred and seventy diameters. This instrument magnifies more than did any of the twenty-six microscopes bequeathed by Van Leeuwenhoek to the Royal Society of England which were carried to London by Martin

[1] P. J. Haaxman, "De Ontdeker der Infusorien," S. C. van Doesburgh, Leiden, 1875.

[2] J. Quekett, "Practical Treatise on the Use of the Microscope," H. Bailliere, London, 1855.

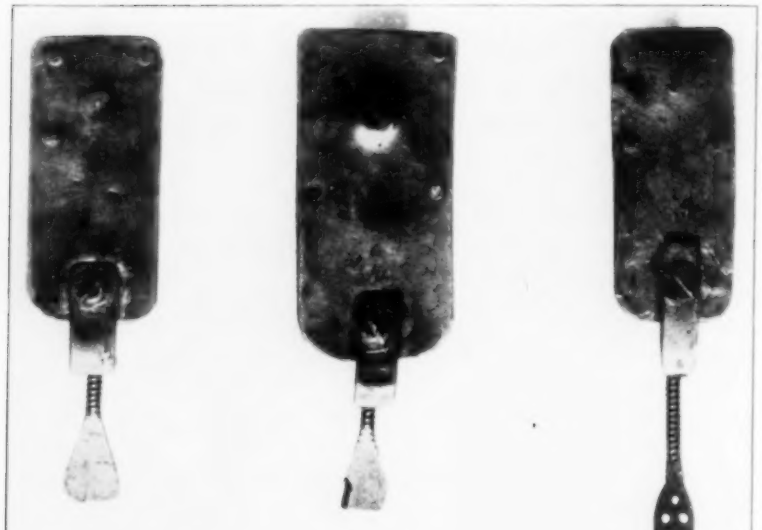


FIG. 2. FRONT VIEWS OF THREE MICROSCOPES

MADE BY VAN LEEUWENHOEK, WHICH ARE EXHIBITED AT THE RIJKS MUSEUM VAN OUDEHEDEN AT LEYDEN, HOLLAND. THE PHOTOGRAPHS SHOW THE EXACT SIZE OF THE MICROSCOPES.

Folkes, a president of the society, and which have mysteriously disappeared. According to Baker, who examined these microscopes, the highest magnifying power was one hundred and sixty diameters and the lowest forty.[1,2,3,4,5]

Henry Baker (1692–1774) was an English naturalist, an authority on microscopes, the author of "The Microscope Made Easy" and "Employment for the Microscope," a member of the Royal Society of England and the recipient of the Copley gold medal of this society for "Microscopical Observations on the Crystallization of Saline Particles." Baker had these twenty-six microscopes in his care for three years and says they were very serviceable. A description of the microscopes made by Van Leeuwenhoek was written by Baker in 1740, and was published in the *Philosophical Transactions* of the Royal Society of England of that year. Baker says:

> All the parts of these microscopes are of silver, and fashioned by Mr. Leeuwenhoek's own hand, and the glasses, which are excellent, were all ground and set by himself, each instrument being devoted to one or two objects only, and could be applied to nothing else. This method induced him to make a microscope with a glass adapted to almost every object, till he had got some hundreds of them.[2]

The three photographs (Figs. 2, 3 and 4) form the nucleus of my paper. They show several views of three microscopes constructed by Van Leeuwenhoek. These microscopes are exhibited at the Rijks Museum van Oudheden at Leyden, Holland. I am greatly indebted to Dr. A. E. J. Holwerda, the director of the Rijks Museum van Oudheden, for his interest and great care in obtaining these photographs for me.

Dr. Holwerda has written me that microscopes invented by Van Leeuwenhoek are in the possession of Mr. F. A.

[3] P. E. Launois, "Les Pères de la Biologie," C. Maud, Paris, 1904.

[4] W. B. Carpenter, "The Microscope and its Revelations," J. and A. Churchill, London, 1891.

[5] Daremberg, C. "Histoire des Sciences, Médicales," J. B. Baillière et Fils, Paris, 1870.

Haaxman, a resident of The Hague, 2 Schuystraat, No. 114. Only two other microscopes made by Van Leeuwenhoek still exist, to my knowledge—one is at Gouda and the other at Utrecht.

My description of the photographs seen in Figs. 2, 3 and 4 is substantially the same as that given by Baker of his drawings in 1740.[2] Front views are seen in Fig. 2; rear views in Fig. 3, and oblique and side views in Fig. 4, all being the exact size of the instruments. Two plates are riveted (best seen in Fig. 4 at right). Between these plates a small biconvex lens is let into the socket, and a hole drilled in each plate for the eye to look through the lens. A limb of metal bent at right angles is fastened to the plates by a screw (Fig. 2). Through this bent limb of metal a long fine-threaded screw (Figs. 3 and 4) runs which turns in and raises or lowers the stage whereon is fastened a pin for the object to be attached to. This pin can be turned about by a little handle (best seen in the photographs left and right of Fig. 3 and the left in Fig. 4). The stage itself is adjusted to or from the lens by another larger screw which passes through the stage in a horizontal position, and when the screw is turned, the stage is forced from (at left in Fig. 4) or brought nearer to (at right in Fig. 4) the lens. If the object to be examined was solid it was placed upon the end of the pin, but if fluid it was placed upon a thin glass or mica plate and fastened to the object holder by wax or glue.

Figs. 5 and 6 (from Baker) show the front and rear views respectively of a silver-bronze microscope made by Van Leeuwenhoek. This microscope had two lenses (e-e), so that similar or dissimilar objects might be examined by him in sequence and thus be readily compared.

Carpenter says of the microscopes made by Van Leeuwenhoek that "nothing was known of his instruments except that they were simple microscopes even down to so late as 1709."[4] "Is it not strange," says Harting, "that the dis-

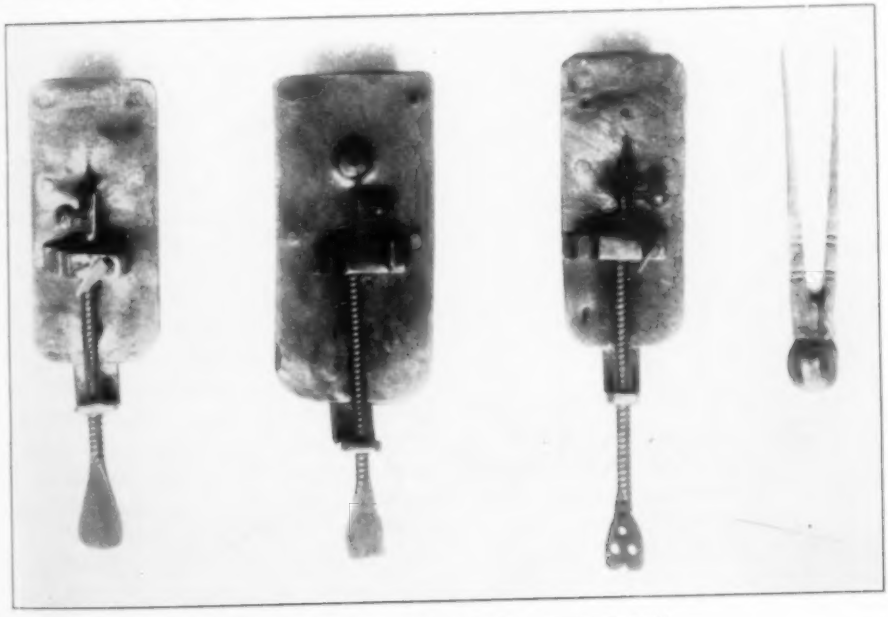


FIG. 3. REAR VIEWS OF THE SAME

A SMALL INSTRUMENT IS SEEN AT THE RIGHT.

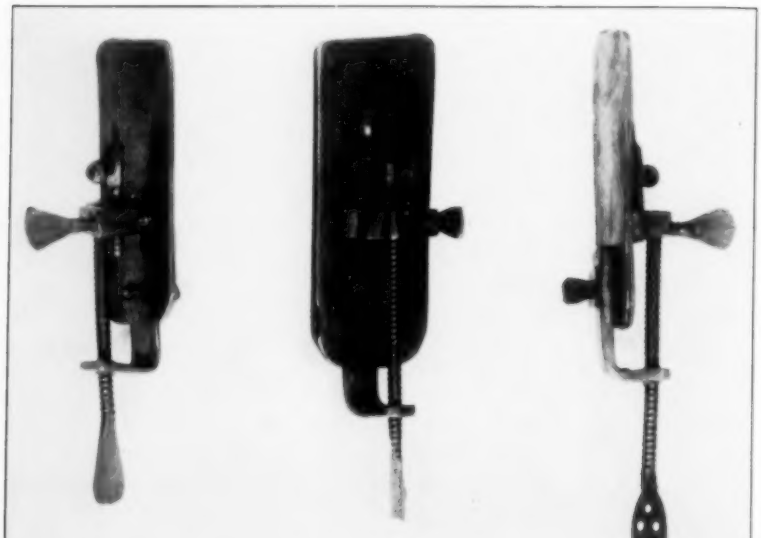


FIG. 4. OBLIQUE AND SIDE VIEWS

covery of an instrument so inherently necessary for the investigation of an entirely new world should attract so little attention that for years its existence was but little known outside of the walls of the house of its inventor?"[1]

Van Leeuwenhoek had several standards for measuring objects with the microscope, one being a grain of sand which measured arbitrarily, according to him, one thirtieth of the thickness of a thumb. He sometimes compared the size of an object either to that of a millet seed or a grain of wheat or to the thickness of a hair of the head or beard. After he had discovered the erythrocyte of man he took its diameter as his standard of measurement.[5]

On August 15, 1673, while examining his blood, Van Leeuwenhoek found it consisted of a transparent fluid in which little solid bodies were suspended. These bodies he called globules, and he noted that the color of the blood depended upon them. This discovery was transmitted to the Royal Society on April 24, 1674. Later he found that these globules were disk-shaped, and he called them blood disks (bloedschijfjes). One hundred mammalian blood disks in a row, according to him, were equal to the diameter of a grain of sand or one thirtieth the width of a thumb, and one disk was equal to two thousandth of the width of a thumb.[1] He examined the blood of the ox, sheep and rabbit, and of fishes, birds and reptiles. He called the mammalian erythrocytes globules because when he first saw them he thought they were spherical. He designated the erythrocytes of birds, reptiles and fishes particles because of their flattened oval appearance. His drawings attest that he distinguished a nucleus in each particle. He described the distortion and compression of the erythrocytes as they pass through the capillaries, noticed that upon the addition of water the erythrocytes changed their shape and saw that the area at the center of the mammalian erythrocyte was lighter in color.[5]

He was not the first to discover the erythrocyte. Kirscher in 1650 had written of having seen little bodies, which he described as little worms, in the blood of patients suffering from fever. Swam-

merdam saw the frog's erythrocyte in 1658, but did not publish his discovery. Malpighi in 1661 saw the hedgehog's erythrocytes but mistook them for fat globules.

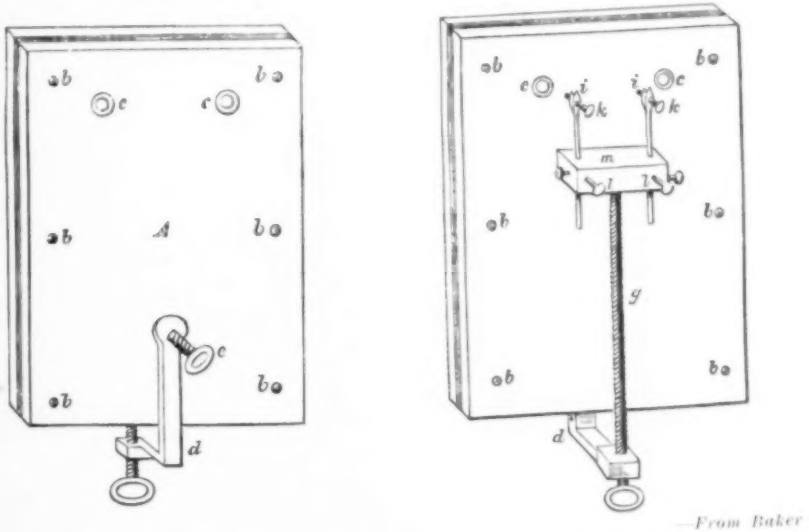
In a letter to L. van Velthuyzen, May 11, 1679, Van Leeuwenhoek complained of the little help he obtained from his scientific colleagues in Delft. "I have now and then made known that I was anxious to examine the blood of sick persons, but I have never been able to obtain any such blood, therefore I have made no further examination of the blood."[1]

Van Leeuwenhoek recognized the canals in bone, afterwards called Haversian canals, and the bone cells in their lacunae; he notified the Royal Society in 1674 that bone consisted of little balls, "bolletjes"; but in 1678 he changed his opinion. He then said the little balls were the ends of "little tubes" and that dried bone consisted of different kinds of tubes.[1]

He was very sensitive of any distrust concerning his discoveries and in a letter to the Royal Society said:

> Whenever I am in doubt or question what I see I say so. Many can not understand my writings and frankly say they do not believe me. I console myself because I try to discover facts only. As soon as I find that I have made a mistake I am always willing to recognize it.[1]

In 1674 when Van Leeuwenhoek was forty-one years old, the anatomist Reinier de Graaf (1641–73), appreciating the value of Van Leeuwenhoek's discoveries, which were known only to a small circle, entreated him to write of some. This Van Leeuwenhoek did, and his thesis entitled "A Specimen of Some Observations Made by a Microscope Contrived by Mr. Van Leeuwenhoek, Concerning Mould upon the Skin, Flesh,



—*From Baker*

FIG. 5. FRONT VIEW OF A SILVER-BRONZE MICROSCOPE MADE BY VAN LEEUWENHOEK. LITTLE HOLES WERE DRILLED THROUGH THE PLATES AT *c–c*, THE PLATES HOLLOWED OUT AT THESE SPOTS AND BICONVEX LENSES PLACED IN THE HOLLOWS AND THE PLATES RIVETED.

FIG. 6. REAR VIEW OF FIG 5

THE OBJECTS FOR EXAMINATION WERE FASTENED ON THE PINS *i–i* WHICH COULD BE TURNED BY THE HANDLES *k–k*. TWO OBJECTS COULD BE BROUGHT INTO PROPER POSITION BEFORE THE LENSES *c–c* BY THE SCREWS *g–l–l–k–k*. SIMILAR OR DISSIMILAR OBJECTS COULD BE EXAMINED IN SEQUENCE BY VAN LEEUWENHOEK.

—*From Hanxmann*

FIG. 7. THE MEDAL PRESENTED VAN LEEUWENHOEK BY THE ROYAL SOCIETY IN 1679, WHEN HE BECAME A MEMBER OF THIS SOCIETY. LEFT: A MEDALLION OF VAN LEEUWENHOEK IS SEEN. RIGHT: ILLUSTRATIONS OF A PLANT, A BEE-HIVE AND THE CITY OF DELFT, WITH A QUOTATION FROM VERGIL.

etc.; the Sting of a Bee, etc." was read by De Graaf at the meeting of the Royal Society of England on May 19, 1675.[1] For nearly fifty years thereafter Van Leeuwenhoek continued transmitting to the Royal Society accounts of his discoveries, often accompanied with illustrations. He sent one hundred and ten communications to this society and twenty-seven to the French Academy of Sciences. As he had no knowledge of any language except his own he wrote in Dutch and had his writings translated into Latin.

Van Leeuwenhoek was the first to see living micro-organisms. In fact he is regarded as the discoverer of both bacteria and infusoria. He announced to the Royal Society (October 9, 1676) that he had discovered what he called animalcules (zeer kleine dierkens), in rain, snow, well and other waters, also in water in which pepper or ginger had been soaked. In a letter to Constantin Huygens, dated November 7, 1676, he says that about the middle of September, 1675, he had discovered animalcules in rain-water which had stood in a barrel for several days, and that they were ten thousand times smaller than the animalcules seen by Swammerdam and named by him water-fleas or water-lice. "We can easily conceive," says he, "that in all rain-water which is collected from gutters in cisterns, and in all waters exposed to the air, animalcules can be found; for they may be carried thither by the particles of dust blown about by the winds." He declared that after boiling and hermetically sealing the water in a vessel the animalcules could not be found.[1,2]

The report of this discovery of animalcules by Van Leeuwenhoek in 1676 created such a sensation that the Royal Society of England held several meetings during 1677 for the special purpose of confirming his claim. His discoveries had met with much opposition, especially that of animalcules in rain and other waters. He was considered illiterate, and for this reason his ability to discover anything worthy was regarded as unpromising.

The Royal Society on April 5, 1677, requested Nehemiah Grew to make experiments having as their aim the confirmation of the claim of Van Leeuwen-

hoek to the discovery of the animalcules in rain-water and pepper-water, and to report his findings to the society. On October 15, 1677, the Royal Society asked Robert Hooke to make investigations similar to those being conducted by Grew. Hooke and Grew having tried and been unable to see these animalcules with their microscopes, the Royal Society advised them to have microscopes constructed with a greater magnifying power and employ them in searching for the animalcules. However, Hooke made glass tubes of various sizes, "some not thicker than ten times that of a hair from the human head," and in these tubes he placed the suspected water. He imagined that these tubes would increase the magnifying power of the microscopes used by him and Grew and thus enable them to see the animalcules on that side of the glass tubing which was most distant from the lens of their microscopes. Hooke and Grew reported again to the Royal Society, November 1, 1677, their inability to find the organisms, whereupon they were again advised to prepare pepper-water, to have better microscopes made and to examine the pepper-water with them.[1]

Having heard of the many discussions at the several meetings of the Royal Society relative to his discoveries and of the doubt in the minds of some regarding the validity of his claims, Van Leeuwenhoek furnished witnesses who had seen what he had seen: two clergymen, one notary and eight other trustworthy persons who had seen the animalcules moving in pepper-water. One group of witnesses said there were ten thousand animalcules in a single drop; another claimed there were thirty thousand, and still another asserted there were forty-five thousand. The size of the drop was that of a grain of wheat.[1]

At a meeting of the Royal Society held a week later, November 8, 1677, Hooke reported that notwithstanding he and Grew had soaked pepper berries in water for two or three days and had examined this water with a more powerful microscope they could find no animalcules. Mr. Henshaw, vice-president of the Royal Society, who never doubted the claims made by Van Leeuwenhoek, said that "possibly as it was winter, it was not the right time to see these animalcules," and he added that he had an acquaintance who had been in Holland the previous summer who said Van Leeuwenhoek had demonstrated them to him. Despite Mr. Henshaw's statement Dr. Wistler replied "that these imaginary beings were indeed nothing else than little grains of pepper floating in the water and not animalcules." Wistler's declaration was strongly opposed by Dr. Mapletoft, who affirmed that Van Leeuwenhoek had assured him that he had seen the animalcules alive as well as dead and that he had seen them dead in the pepper infusion soon after he had added vinegar. Hooke sided with Wistler in this dispute, and stated that he could find nothing but pepper in the pepper-water. Finally it was decided that Hooke procure a more powerful microscope, search for the animalcules and report at their next meeting.[1]

At the next meeting of the Royal Society held one week later (November 15, 1677), Hooke reported that after making pepper-water, with clear rain-water and a small quantity of pepper berries and allowing this mixture to stand nine or ten days, he could see a great number of animalcules swimming back and forth, each having the shape of an egg or a clear bubble. According to his calculation each animalcule was one hundred thousand times smaller than a mite. At this meeting, Hooke having demonstrated the animalcules to the satisfaction of every one, it was resolved that the truth of Van Leeuwenhoek's discovery be recorded, and that the names of all those who had witnessed the demonstration be likewise recorded.[1] Sir Christopher Wrenn was present at this demonstration. It was in the early part of the last quarter of the seventeenth century that the world was amazed at the discovery of a "new-world-of-innumerable-beings," differing in size, shape and movement, which were

beheld in a single drop of water by means of "an artificial eye" devised by a strong man endowed with marvelous industry. Up to this time the cheese-mite was the smallest animal in creation. Pasteur and Lister came two hundred years later.

Van Leeuwenhoek was much talked of, especially in England. His discoveries exercised the greatest influence upon the anatomy and physiology of this period. The scientific world, agitated concerning them, was anxious to examine the microscopes made by Van Leeuwenhoek and was curious to learn how he manufactured the lenses through which he was revealing a new world.

Van Leeuwenhoek was elected a member of the Royal Society in 1679 and a medal of the society was presented him. On the obverse side of this medal (Fig. 7) is seen a medallion of Van Leeuwenhoek. The translation of the Latin reads: "Ant. Leeuwenhoek, member of the Royal Society of England." On the reverse side illustrations are seen of a bee-hive, a plant and the City of Delft. The Latin inscription from Vergil may be translated: "His work was in little things, but not little in glory."

On November 23, 1681, at a meeting of the Royal Society, Mr. Henshaw said he surmised that the lenses used by Van Leeuwenhoek were ground in an unusual way, that Van Leeuwenhoek illuminated the objects he examined under his microscopes in a special way and that he had a room especially fitted up in which he conducted his investigations.[1]

Hooke remarked that the lenses constructed by Van Leeuwenhoek were only what he had said they were in his "Micrographia" (1665); "melted glass balls, whole or cut in halves and formed into a lens." Mr. Henshaw suggested that because of the newness and the greatness of the discoveries made by Van Leeuwenhoek he be requested to make known his methods not only of grinding and polishing his lenses but also of the construction and usage of his microscopes. When this request of Mr. Henshaw was presented to Van Leeuwenhoek he replied, "I agree with you." We shall see, however, that he had no intention of complying with this request. He kept his methods secret. When a question was asked that he did not care to answer, he did not reply. A letter from Thomas Molyneux, dated March 14, 1685, was read at the meeting of the Royal Society April 1, 1685, wherein he stated, "It was not possible to get one of Van Leeuwenhoek's microscopes for money." A letter of Huygens states that Van Leeuwenhoek would not allow the Landgrave of Hessen-Cassel to handle his microscopes, fearing they might be copied. Once a German came to Van Leeuwenhoek and asked if he would sell him a microscope. Van Leeuwenhoek anwered promptly, "Nein bei meinen Leben nicht." When he was asked why he made so many microscopes and would not sell any, he remained silent. Van Leeuwenhoek evidently did not wish all his technique to die with him, because he willed twenty-six microscopes to the Royal Society of England, but he appears to have been desirous of concealing during his life almost all that he knew pertaining to the construction of microscopes and their usage. In fact, he states in a letter to Henry Oldenberg, the secretary of the Royal Society, that he had microscopes of a greater magnifying power than those he was in the custom of exhibiting, which he kept for his own use to examine micro-organisms in water.[1] William Molyneux, astronomer and mathematician, a brother of Thomas Molyneux, writes in his "Dioptica Nova," published by B. Tooke at London in 1692:

> The Heer Leeuwenhoek of Delft in Holland has lately applied himself with great diligence to the use of microscopes: of which instrument he thinks he has a better kind than was ever yet known. When I visited this Gentleman at Delft he showed me several that indeed were very curious, but nothing more than what I had ordinarily seen before, being composed only of one single very minute glass-sphere or hemisphere placed between two very thin pierced

laminae or plates of brass, and the object was brought to its due distance before the glass by a fine screw: but, for his best sort, he begged our excuse in concealing them.

In 1747, twenty-four years after the death of Van Leeuwenhoek, his microscopes and other scientific effects were placed on sale. The catalogue for the sale was printed in Latin and Dutch by the city printer of Delft, Reinier Boitet. The following is a translation of an excerpt from this catalogue.

The catalogue of the far-famed microscopes made with much trouble and expense during many years by the deceased Van Leeuwenhoek, and left by him, who during his noble life was a member of the Royal Society of England, will be sold on Monday, May 29, 1747, in the city of Delft, in the guild chamber of Saint Luke, in the morning from 10 to 12 and in the afternoon from 2:30 to 5.[1]

The frontispiece of this catalogue is an engraving of a cabinet for microscopes. Two children, one holding a microscope in the hand, are examining the microscopes. The catalogue also contains an engraved portrait of Van Leeuwenhoek. The microscopes listed are three gold, one hundred and forty-seven silver, five silver and copper and three hundred and seventy-five copper. On page 45 there is an inserted sheet containing the names of the purchasers and the amount paid for their purchases. Twelve pieces of apparatus (Fig. 8) are also listed, which were used for holding, in a fixed position, a glass tube partly filled with water and just large enough to contain a small eel. The tail of the animal was placed uppermost so that the circulation of the blood might be examined by a microscope attached to the upper part of this apparatus. Eight of these pieces were constructed of silver and four of copper. The returns from the sale of these microscopes amounted to seven hundred and thirty-three guldens and three stuivers. One gold microscope brought twenty-three guldens. A silver one sold for ten guldens. Those of copper brought fifteen stuivers to three guldens.[1] The value of a gulden to-day, with us, is about forty cents, and that of a stuiver about two cents.

Haaxman says:

It appears that all these microscopes remained in our land [Holland] judging from the names of the buyers. The name of Dirk Haaxman appears very often on the list of purchasers. It is surprising there are not more of these microscopes in my family.

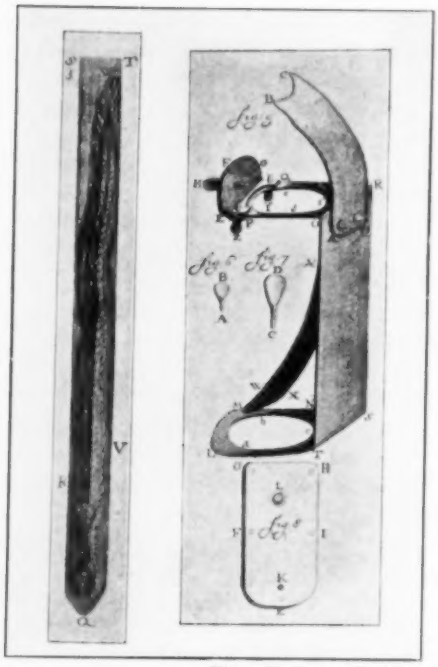
Haaxman also states that when a lad he examined insects with a microscope resembling one of those made by Van Leeuwenhoek, but attaching no more value to this instrument than to any other toy he lost it.[1]

On June 9, 1699, Van Leeuwenhoek wrote the Royal Society:

Regarding my "glasses" [microscopes], I will not boast. I make them as well as is in my power. For many years the lenses have been made better and better and been better mounted. On the grinding and the mounting of a lens much depends. I have known those who ground lenses and who considered themselves competent to do so, but were not fitted for the work, because they could not tell an incorrectly ground lens from a correctly ground one. As one is able to discriminate between a good and a poor lens by so much is one able to fashion a perfect lens. And if one has made a perfect lens and tries to make new discoveries with it, one must not judge his discoveries at first sight, but must see them often. I have seen often. To brag, to make a noise about a thing is commonly called to see through a "glass" [magnifying glass]. When one looks through a "glass" [microscope] at first one may see one thing and later another thing, and when one investigates the findings they may be false. It is very easy for people, even those who are accustomed to look through "glasses" to be deceived, to be misled.[1]

Leibnitz and others urged Van Leeuwenhoek to establish a school in which students might be instructed in his methods of making lenses. He answered Leibnitz:

I can see nothing coming from the establishing of a school in which young men might be taught the cutting and grinding of lenses. Many students have come to Leyden because of my discoveries and my method of making lenses. There is much in the making of lenses and the



—*From E. C. van Leesum*

FIG. 8. TUBE AND HOLDER

LEFT: A SMALL GLASS TUBE PARTLY FILLED WITH WATER WHICH WAS JUST LARGE ENOUGH TO HOLD A SMALL EEL. RIGHT: APPARATUS USED IN CLAMPING THE TUBE, SO THAT, WHEN THE MICROSCOPE (E–F–G–H–I) WAS FASTENED TO ITS UPPER PART BY THE SCREW H THROUGH THE HOLE K IN THE MICROSCOPE, THE EYE MIGHT BE FIXED UPON THE LENS AT L AND THE TAIL OF THE EEL EXAMINED.

discovery by them of things concealed from our eyes, and because of this, most of these students propose to obtain money through science or through learning to become well known. It is plain to me that out of a thousand persons not one would be fitted to give himself to such study, because it takes much time and money, and in order to accomplish anything one's entire mind must be given up to the study.[1]

On March 13, 1716, he wrote Leibnitz:

I have never had any desire to teach. If I instructed one I should have to instruct others or they would accuse me of partiality. I wish to remain free. I do not look for money from my work, inventions or discoveries; and I do not try to get anything out of them. And, further, to do good work one must study, spend money and go into the work with all one's soul, which is surely a work not attractive to most young people.[1]

In a communication to the Royal Society, November, 1677, Van Leeuwenhoek states he had received a letter from Professor Theodore Craanen, of Leyden, requesting him to show some of his discoveries to his nephew (Johan?) Ham, a medical student at the University of Leyden, and that he complied with this request. Van Leeuwenhoek continued:

Ham visited me a second time, in August, 1677, when he brought me, in a glass vessel, the spermatic fluid of a man who had cohabited with an unhealthy woman. He said he found living "animalcules" with tails, in this fluid and that they lived only twenty-four hours. He thought the presence of the animalcules was caused by the decomposition of the fluid. Further, he noticed that when he gave the man turpentine internally these animalcules died.

Van Leeuwenhoek examined this fluid, which Ham brought him, confirmed Ham's discovery and made many researches on the healthy spermatic fluid of man and of a great number of animals and found what he called "little worms" or "spermatic animalcules." He studied their shape and movements and thought there were both male and female spermatic animalcules. He said that a line formed by one hundred of them would not be as thick as a hair, that fifty thousand of them would not cover a

—*From R. J. Petri*

FIG. 9. A MICROSCOPE WITH A REFLECTOR

WHICH WAS MADE BY VAN LEEUWENHOEK. THE REFLECTOR SIDE IS ON THE LEFT; THE OBSERVER SIDE ON THE RIGHT. THE ALLEGORICAL FIGURE, INVESTIGATION, IN FIG. 10, IS HOLDING A MICROSCOPE SIMILAR TO THIS ONE.

grain of sand and that one could count more spermatic animalcules in the wood louse than there are men upon the surface of the earth. It is said that "the report of Ham's discovery to the Royal Society by Van Leeuwenhoek made so much noise that it was spoken of at the court of Charles II, who expressed a desire to see "these strange beings."[1, 6]

It is not clear whether Ham, of Arnheim, or Nicolas Hartsoeker, another Hollander, was the first to discover the spermatozoon. Hartsoeker (1656–1725) was an astronomer and a natural philosopher. He made great discoveries, but his paradoxical mind caused him to stray from facts. He taught at Amsterdam, was honorary professor at Heidelberg and toward the end of his career accepted the chair of mathematics and philosophy at Düsseldorf. He had some highly eccentric metaphysical philosophical notions, and was of a singularly disputatious temper.

Hartsoeker in his "Extrait Critique" alludes to Van Leeuwenhoek as follows:

> Among a quantity of useless observations there are some that are good and serve the advancement of learning. I have never been so surprised as when our author, whose ability is below the average, spoke as he did of globules in the blood and in milk, and my astonishment was great when I heard that well-known physicians and professors of philosophy and of medicine have cited him with praise respecting his beautiful discovery of the globules in the blood and have adopted his galimatias. I visited him three times. I went there the first time with the mayor of Rotterdam and my father about the end of 1672 or beginning of 1673, which visit he well remembered, as we shall see. The second visit I made alone, towards the end of 1679, on my return from Paris. This visit was made half in the street and half in his doorway. His actions toward me excited my enmity, because I objected to his ridiculous ideas on anatomy, to which he could not reply. How do you dissect a flea or a moth so as to draw the testicles from the body and open the testicles and take the spermatic fluid out so as to see that it is filled with little animals, the form of little eels, very long and very thin? What glasses do you use to make this anatomical demonstration? If the lens is small you have not enough light and if the lens is large it does not enlarge enough? What knives do you use; the sharpest and the finest would crush the structure quicker than open it? And following that, no doubt on account of my objections, he left me abruptly, saying he had work to attend to.[1]

Hartsoeker tells us that the third time he called upon Van Leeuwenhoek was in 1697 or 1698, twenty years after his second visit, and that he was accompanied by the mayor of Delft. Van Leeuwenhoek was prepared to receive his guests and to show them some of his discoveries. The mayor presented Hartsoeker to Van Leeuwenhoek, "on which Van Leeuwenhoek," says Hartsoeker, "viewing me with disdain, refused to show us anything, and it would not have taken much to have had him throw us out of the house."[1] Hartsoeker says of Van Leeuwenhoek:

> All that he has said and has repeated a thousand times are only just so many words, and as for his sketches demonstrating his observations, they mean nothing at all and are only a confused lot of drawings.[1]

The following is an extract of a letter from Van Leeuwenhoek to Leibnitz: "I well see that many learned men will accept neither my discoveries nor my ideas. Therefore I prefer, rather than dispute with them, to solace myself with the hope they may later accept them."[3]

Many were skeptical regarding the discovery of the spermatic animalcules; however, among those who were not was Leibnitz, who wrote Van Leeuwenhoek, September 28, 1715, that "the learned Vallisnieri of Padua" distrusted the discovery of Van Leeuwenhoek, but that he thought of writing concerning this discovery and that he would give Van Leeuwenhoek credit for his part in it. Van Leeuwenhoek answered: "We have a Dutch expression: 'one blond crow does not make a cold winter.' If Vallisnieri is against me there are those who are with me."[1]

On September 25, 1699, Van Leeuwenhoek wrote Grew, that

[6] K. Sprengel, and A. J. L. Jourdan, "Histoire de la Médecine," Paris, 1815.

FIG. 10. AN ALLEGORICAL FRONTISPIECE

BY PETER RABUS, IN THE SECOND VOLUME OF VAN LEEUWENHOEK'S WORK PUBLISHED IN 1695.

notwithstanding so few people believe so many animalcules can be obtained in so little fluid, which I know to be a fact, and which the Royal Society of England doubted at one time, I will not be offended by any one who may reject my views; and as sure as I was of having discovered animalcules in water, so sure am I about my discovery of spermatic animalcules in the spermatic fluid of man, birds and fishes. It will suffice me if I obtain credit only from you and other eminent and learned men.[1]

A detailed announcement of the discovery of the spermatic animalcules was made December 17, 1698, by Van Leeuwenhoek to the ex-mayor of Rotterdam, Harmen van Zoelen.[1]

Dr. Becker[1] in his "Närre Weisheit und Weise Narheit," 1682, says:

Die Welt still steht,
Und nicht umgeht,
Wie recht die Gelehrten meynen;
Ein jeder ist Seines Wurms vergewyzt,
Copernicus des Seines,
Und also Herr Leeuwenhoek des Seinen.

Malpighi and Van Leeuwenhoek might

be called the completers of Harvey's discovery, because Malpighi (1661) discovered the circulation of the blood in the capillaries (pulmonary capillaries of the frog),[3] and because Van Leeuwenhoek (1686) studied and described the circulation of the blood in the capillaries of the web of the frog's foot, of the fin of fishes, of the tail of the tadpole and eel, of the bat's wing and of the ears of young rabbits. Van Leeuwenhoek observed and proved the continuity of arteries and veins by means of the capillaries and said it was difficult to determine where the artery ended and the venous radicle began.[1] He says:

If now we have been fortunate enough (for which we have longed so much, and diligently looked in vain for many years) to expose so clearly the circulation of the blood and its passing from the arteries into the veins in the aforesaid frogs and fishes, we shall not be satisfied with it, but we shall do our best to examine it also in other animals and if possible to discover it there also.[7]

The following is an extract from a letter of Van Leeuwenhoek to the Royal Society, July 10, 1696, relative to his discovery of the capillaries:

I took several of the least sort and put them into my small tube (partly filled with water) so that they could but just go into it. [See Fig. 8.] When I fixed these small eels before the "glass" and fixed my eye upon the fin near the tail, I saw with greater admiration than ever I did in my life before, the circulation of the blood, and that in so many sundry places; so that if I should delineate the little space composed thereof, it would not seem credible to most men.[7]

Van Leeuwenhoek called the capillaries "very small arteries" or "very small veins" or "very little vessels." He saw that they had walls, which some observers doubted. He detected the erythrocytes passing along the lumen of the vessels in single file. He noted that the blood may flow rapidly or slowly in the capillaries, or that it may stop and then flow in the opposite direction; that cold and heat affected the flow, and he attempted to measure the velocity of the flow.[1, 5] He says:

The motion of the blood in these tadpoles exceeds that in all the other small animals and fishes I have seen; and seeing this has been so recreating to me, that I do not believe all fountains, or waterworks, either natural or made by art, could have pleased my sight so well. And now at last I spied a small artery; that notwithstanding it is so small that I judge but one small globule of the blood could pass through it. . . . Yet what was most remarkable was to see the manifold small arteries that came forth from the great one, and which were spread into several branches, and turning came into one again, and were reunited, that at last they did pour out the blood again into the great vein; this last was a sight that would amaze any eyes, that were greedy for knowledge.[8]

He tells of the elastic reaction of arteries and how the expansion of the arterial wall travels distally along the arteries as the pressure is increased within them.[5] He writes of having seen the fibrillae and transverse striation of voluntary muscle; the muscle bundles in the ox's tongue; the vascular plexus surrounding the muscle fibers in the diaphragm of a lamb, and the arrangement of the muscle cells of the heart (rediscovered by Kolliker, 1863) which he called "concatenatio fibrarum."[5] He states that the optic nerve of the ox and the horse has no central canal, as the ancients thought, but is composed of filaments or juxtaposed canaliculi filled with globules; the shaking of the latter by the impression of light caused the transmission of impulses to the brain. His observations on the structure of the nervous system, which were his least exact, were reported to the Royal Society between 1674 and 1685. Later (1715) his idea of a nerve trunk had improved with observations, because he described the nerve sheath, the nerve fasciculi and

[7] E. C. Van Leesum, "Old Physiological Experiments," dedicated to the Ninth Congress of Physiologists at Gröningen, E. J. Brill, Leyden, 1913.

[8] J. C. Dalton, "Doctrine of the Circulation," H. C. Lea's Sons and Co., Philadelphia, 1884.

the nerve fibers, saying that the nerve fibers were so thin that more than one thousand of them could be found in a nerve trunk which had a diameter equivalent to the sum of the thickness of three hairs taken from the head.[5] He made transverse sections of nerves and of the spinal cord and remarked that the transverse sections of the medullated nerve fibers in these structures, which he mistook for tubules, consisted of a membrane (rediscovered by Schwann, 1838) containing a liquid, and that in the center of this liquid there was a central point (axon or dendron) or corpuscle as he called it.[5,6] He described the vascular structure of the pia mater and the blood vessels (vasa nervorum) in the nerve trunk.[6]. He studied the rods and cones in the retina,[9] the lamellated structure of the crystalline lens, which had been discovered already by Stenon,[5,6] and the fat globules in milk.[1] He saw globules in adipose tissue and thought he saw globules in the brain and cord.[5] He found living spermatozoa in the uterus and tubes of a bitch and asserted that they and not the spermatic fluid played the essential part in reproduction.[10]

In his communication to the Royal Society (1679) Van Leeuwenhoek states he had seen the dentinal tubules or canaliculi in the teeth of man, elephant, horse, pig and cow. His communication was accompanied by drawings of these tubules. He observed that the tubules ran from the interior of the tooth to its periphery; that processes of the pulp tissue (fibers of Tomes) ran into the tubules, and he thought these tubules were characteristic of dentin. He said that they could be seen only when highly magnified and that they had a diameter of 1/5,400 of the width of the thumb. It was not until 1835 that this work of Van Leeuwenhoek on the teeth was confirmed by Retzius and Purkinje.[11,12]

The dentinal tubules permit the passage of lymph, ink, oil, dyes, etc. Van Leeuwenhoek saw blood stains in the dentinal tubules as later did Felix Dujardin (1801–60), who saw blood stains in the dentinal tubules of persons who had died of cholera or who had been asphyxiated by carbon monoxide; the infiltration of the dentinal tubules by the decomposed blood reaching the dento-enamel junction of the tooth (the erythrocytes are too large to enter the tubules) gave the tooth a brownish-red color.[5]

Van Leeuwenhoek described the squamous epithelial cells of the epidermis, having found them in the cerumen of the ear and the sweat of the hands and face, and said they resembled fish scales and that they were replaced continually by new scales. He found squamous epithelial cells in the secretions of the mouth and vagina. He made comparative studies of normal epidermis, epidermis of cicatrices and keratosis, described the Negro's skin and said that the color of the skin depended upon the epidermis. He saw the epithelium of the intestines and gave an accurate description of hair.[5] He gave the name "filamenta seu stamina tenuia tendinum" to connective tissue.[9] He made microscopical studies of insects and their metamorphoses, of the parasites of man and animals, of the structures and germination of plants, of grain, of crystals and tophi. He discovered and studied the movements of the vinegar eel in vinegar and the vibrios (treponema microdentium and macrodentium?) in the tartar on teeth.[3] He found micro-organisms in the mouth and showed their presence to be greater in the "food rests" between the teeth than elsewhere.

[9] J. G. Bernard, "Histoire des Microscopes," Ollier-Henry, Paris, 1886.

[10] A. Donné, "Cours de Microscopie," J. B. Baillière, Paris, 1844.

[11] Dictionnaire Universal d'Historie Naturelle, Fortin, Masson et Cie, Paris, 1843.

[12] Bayle et Thillaye, "Biographie Médicale par Ordre Chronologique," Adolphe Delahays, Paris, 1855.

Van Leeuwenhoek discovered (1680) minute globular or ovoid particles in fermenting fluids. This was the first observation of the yeast plant.[13] In 1837, both Schwann and Latour discovered the organic nature of yeast, and showed that the yeast-plant causes fermentation. He denied the then accepted theory that fermentation took place in the blood because he was unable to see air bubbles in the circulating blood.[6] He showed that weevils of granaries are grubs hatched from the eggs deposited by winged insects, and are not bred in and from wheat, as was then believed. He not only described the structure of the flea but also traced its entire history of metamorphoses from the egg. He even noted that the pupa of the flea was attacked and fed upon by a mite. He was the first to discover that the blighting of the young shoots of fruit trees was due to the aphids and not to the ants also found on the trees. He studied carefully the life history of ants. He made studies of the sea-mussel, fresh-water mussel and other shell-fish. He said they were not generated out of the mud or sand, but from spawn. He made careful studies of the ovum of the fresh-water mussel. He showed that eels were produced by the ordinary process of generation, and not from dew. He discovered rotifers, noted their resistance to drought and declared that the resistance was due to the impermeability of the casing in which they were enclosed, which prevented the evaporation of the body fluids. He described the different structures of the stem in monocotyledonous and dicotyledonous plants.[14] It is said that he was greatly pleased when a sailor brought him the eye of a whale, which became a source of many investigations.[3]

He relates, in a letter on July 10, 1696, to the mayor of Amsterdam, Nicolas Witsen, that he had made experiments pertaining to the movement of the earth and that he had discussed his results with Christian Huygens.[1] While examining an opaque object Van Leeuwenhoek used a mirror of polished copper to reflect the light upon it. In all probability Lieberkühn knew of the reflector devised by Van Leeuwenhoek when he constructed his own reflector of polished silver. Lieberkühn, however, is considered the inventor (1738) of the reflector for the microscope.[2, 9] In the allegorical frontispiece of Van Leeuwenhoek's work published in 1695, the central figure representing "Investigation" is seen holding a microscope, made by Van Leeuwenhoek, which is furnished with a reflector (Fig. 10). Petri in his work "Das Mikroskop"[15] has an illustration (Fig. 9), of a microscope with a reflector constructed by Van Leeuwenhoek similar to the one that "Investigation" is holding in the allegorical frontispiece (Fig. 10). Is not this reflector invented by Van Leeuwenhoek a forerunner of many medical instruments? Because Van Leeuwenhoek made contributions to botany, Robert Brown, the English botanist, named a species of plants of New Holland (the old name for Australia) "Leeuwenhoekia," and said: "In Memoriam, Antonii a Leeuwenhoek, micrographi celeberrimi, in cujus operibus plures et perpulchrae observationes de plantarum structura exstant."[1]

In a letter to the Royal Society Van Leeuwenhoek states that he had to kill more than one hundred mosquitoes in order to obtain one perfect proboscis for examination and that he was busy several days in obtaining this specimen.[1] And with reference to his investigations in general he says:

> On these said experiments I have spent more time than people will believe, but I have done them with pleasure. I have not noticed those

[13] J. C. McKendrick, "A Text Book of Physiology," Macmillan and Co., London, 1886.

[14] Encyclopaedia Britannica, thirteenth edition, *s. v.*, Leeuwenhoek.

[15] R. J. Petri, "Das Mikroskop," R. Schoetz, Berlin, 1896.

who said: Why go to so much trouble and for what use? I do not write for them, but only for those who have imagination, who are philosophically inclined and are able to appreciate what I write.[1]

. . . It is to be deplored that medicine is practiced by so many who use poor judgment. Where is the apothecary or surgeon who does not give laxative medicines in mild cases? And in many cases it is the only thing they can do, because most of them have no knowledge of how the body is constructed and they are not competent to question the patient to get at the cause of illness. And it is stated that there are physicians who visit patients and order remedies for them with the object of chasing money into the pockets of the apothecary.[1]

He opposed the method of purging, then in vogue, and said:

Such a powder is sooner a murder-powder than a healing-powder. Can we not call, with justness, that awful stuff which causes such movements of the stomach and intestines a murder-powder? We will take care that these murder-powders do not enter our body and that those who give them keep away from us.[1]

. . . It is strange that many people in our land believe so easily. Let but a "great doctor" come to the land, who announces himself as having made great cures, which he usually does, and come forward with many lies, then such quackery often finds not only an entrance with the common people, but it also goes over to those whom we expect to have better judgment. And when we speak to these quacks regarding their business of which they are supposed to have some knowledge, they are but ignoramuses. Some time ago there came into our land a great lying German, who claimed that by means of a powder which he called "sympathy" he could cure any ill. They brought this quack to my house in a carriage, so that I might admire him. His cure consisted of a powder to be placed in the urine of the patient. After I had listened to the man until he annoyed me, I asked the liberty to tell him my ideas. This was granted, and I told him that I did not believe such stuff and that I considered his cure an impossibility and that all those who had done this same thing before him were tricksters. He cited many cures which did not have a sign of truth, so much so that I was disconcerted by his ignorance, and told him that all who would traffic with him would be cheated. This proved true. Is it not miserable that our nation goes over to such people, when we can be served satisfactorily by our own physicians, our own compatriots, who possess a great many more gifts than the foreigner we have mentioned? We learn by experience that those who are most ignorant of the art and science of healing are those who make the most noise.[1]

Van Leeuwenhoek's opinion was considered so valuable that people came from foreign countries to consult him. Merchants, physicians, surgeons and corporations sought his advice. In 1656, the mayor of Amsterdam, Nicolas Witsen, who was also president of the East India Company, consulted him in behalf of this corporation. He was asked for something to kill the worms in the nutmeg. Van Leeuwenhoek advised that the places where the nutmegs were stored and the ships in which they were imported should be fumigated with sulphur.[1]

He thought many disorders arose from the blood being too thick, because it traveled so slowly through the capillaries, and that much drinking would thin the blood. He applied this theory to himself, so that whenever he had eaten much in the evening, he drank more and hotter coffee next morning, to encourage sweating, and he said "that having eaten so much, an entire apothecary shop would not help me as much as this simple remedy. I noticed that tea would make me sweat in the same way."[1]

Harting says that Van Leeuwenhoek was the first to possess a collection of microscopical specimens and that he excelled in preparing them. In a letter to Leibnitz of November 17, 1716, Van Leeuwenhoek relates: "I have shown two celebrated professors the dead spermatic animalcules which I placed in a thin glass tube twelve years ago, in which we could distinguish very plainly the body from the tail."

The following specimens prepared by Van Leeuwenhoek were advertised for sale in 1747:

Muscle fiber of a whale and of a codfish.

Cardiac muscle (goose). Transverse section of muscle of fish. Desquamated epithelium (skin) of man. Crystalline lens (ox). Erythrocytes (man). Liver (pig). Transverse section of wall of bladder. Bladder of ox. Papillae of tongue (ox). Hair of sheep, bear, beaver, deer. Hair from nose. Desquamated epithelium from the human tongue. Scales of perch. Spinning apparatus of spider. Threads of spider's web. Mandible of spider. Eyes of spider. Spinning apparatus of silk-worm. Brain of fly. Optic nerve of fly. Foot of fly. Mandible of flea. Foot of flea. Eye of beetle. Skin of louse. Mandible of louse. Section of coral. Section of oyster shell. Transverse and longitudinal sections of elm, fir, ebony, linden, oak, cinnamon and cork trees. Sections of nutmeg and of bulrush. Grain of rye. Pieces of white-marble, rock-crystal, diamond, gold-leaf, silver and saltpeter.[1]

For nearly three quarters of a century this patient, industrious and ingenious man examined without order, method or any preconceived idea almost everything attracting his attention and made many discoveries, but his confidence in himself and his instruments also led him into errors and the making of strange assertions. It is said that Van Leeuwenhoek was opinionated and extremely vain and had many controversies.

In a letter to George Garden, of the Royal Society, Van Leeuwenhoek says:

My object is not to remain opinionated because of my own views, but as soon as any one shall give me probable reasons against my views which I can accept, I will abandon my own and go over to another's. And, this the more, because my investigations are made only with the object of discovering the truth, as much as is in my power, and to put the truth before the eyes of all; and with the little talent that I have to withdraw credulity from the world. I know well that my investigations are not coordinated, but that among them there are conflicting discoveries; and because of this I say again that my object is not to hold my opinions any longer than to that time when I would be better informed through my observations, from which it will follow that I will have to go over to other ideas which I will never be ashamed to do.[1]

Haaxman says: "An honest simple righteous character was Van Leeuwenhoek. The more one reads his letters the greater must he be esteemed."[1]

In another letter to George Garden he writes:

Regarding the differences of Swammerdam and De Graaf, I knew these men, they have been at my house many times and I admire their discoveries. And if they were still living they would be red with shame because of their squabbles, that were caused by each laying claim to the priority of having discovered certain organs of generation in the female.[1]

The members of the Royal Society who had long admired the discoveries of the ingenious Hollander were anxious to learn something of the man himself and of his instruments, so they sent Dr. Molyneux to visit him. He writes, February 16, 1865:

I found him a very polite man, very agreeable and really endowed with great natural aptitude, but contrary to my expectation totally illiterate. He is ignorant of Latin, French, English and all other languages except his own, which therefore impedes his reasoning. Not knowing in any way the ideas of others, he has in his own, such assurance that he attempts to explain things in an extravagant and fantastic manner.[1]

Many were envious of Van Leeuwenhoek, but he had many admirers, among them the Duke of Wurtemberg, the Duke of Brunswick, the Landgrave of Hessen-Cassel, Charles II, George I, Queen Anne of England, Frederick II of Poland, Frederick I of Prussia. When Charles III of Spain came to The Hague he delegated Prince Lichtenstein to invite Van Leeuwenhoek to come there and demonstrate some of his discoveries to him. The historian, Girard von Loon, gives the following account of the visit of Peter the Great to Van Leeuwenhoek in 1698:[1,3]

The Czar left The Hague in one of those yachts used on the canals, and arriving at Delft invited the celebrated Antony van Leeuwenhoek to call upon him and bring his incomparable microscopes. Van Leeuwenhoek then had the honor of showing his Imperial Majesty, among

other things, the circulation of the blood in the tail of the eel. This curious observation and others so pleased the Czar that he spent two hours with Van Leeuwenhoek and when he departed, he shook hands with him and thanked him.

Some of Van Leeuwenhoek's works, printed in Dutch, were published at Delft and Leyden, and in 1695 all his writings were gathered and published at Delft in four volumes entitled "Arcana natura ope et beneficio exquisitissimorum microscopiorum detecta, variisque experimentis demonstrata ab Antonio a Leeuwenhoek." Other editions appeared in 1696, 1697 and 1719, and in 1722 the four volumes were republished at Leyden with the title "Opera omnia, seu, Arcana naturae ope exactissimorum microscopiorum detecta, experimentis variis comprobata."[12]

The following is a translation of a description in Latin by Peter Rabus (1695) of the allegorical frontispiece (Fig. 10) in the second volume of Van Leeuwenhoek's work published in 1695:

The Specter of Philosophy, Queen of Science, standing behind the table, is disclosing Nature, formerly concealed but now revealed. Sagacious Investigation, upon whose temples are wings and who is clothed with a robe covered with eyes, has before her the different products of Nature which she is examining with a microscope made by Van Leeuwenhoek, in order to search out how the products are begotten and born. [This microscope is furnished with a reflector. See Fig. 9.] Standing behind Investigation, in the right background, is Diligence, always active. Diligence is guiding Error. Error is represented as a poor one-legged man, whose eyes are bandaged and whose face is disfigured by the ears of an ass. Error is resisting Diligence. Three men are seen in the right foreground who pride themselves upon being philosophers: the first, (kneeling behind Investigation) a superstitious Jew; the second, (standing) a Christian, not less credulous, and the third (at left of the Christian), a Heathen, from the school of Aristotle who carries hidden qualities on his shoulders. The three have not been able to raise themselves to the place where stands Truth, who has no need of seduction and who is crushing horrent Envy under his feet. The Light Divine falls from Heaven and shines upon the microscope of Van Leeuwenhoek.

On November 20, 1719, Van Leeuwenhoek wrote the Royal Society:

I am about to enter my eighty-fifth year; my hands grow heavy and commence to tremble. In saying adieu to you I wish to thank you again for the honor you have done me in making me in 1679 a member of your illustrious society.[1]

Zeal for work continued with Van Leeuwenhoek to within thirty-six hours of his death, when he was found writing his report to the East India Company respecting the presence of gold in a specimen of sand which had been sent him by the president of this company for microscopical examination.[1]

The epitaph on the tomb of Van Leeuwenhoek in "The Old Church" or Church of Saint Hippolytus at Delft was written by his friend Huibert Cornelizoon Poot, "The Robert Burns of Holland."[1, 16] The translation of a part of it reads:

Here lies Antony Van Leeuwenhoek, oldest member of the Royal Society of England, born at the city of Delft the twenty-fourth of October, 1632, and died the twenty-sixth of August, 1723, having reached the age of ninety years, ten months and two days.

You, O wanderer, having respect for old age and wonderful talent, stand in veneration. Here gray science lies buried with Van Leeuwenhoek.

[16] "Description of the Principal Tombs in The Old Church at Delft," published by the Churchwardens, Delft, 1907.

THE TOPOGRAPHIC BASE MAP OF THE UNITED STATES

By J. G. STAACK

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A MOTORIST has written, "Left to myself, I instantly reach for the left-hand door pocket, wherein resides a splendid assortment of maps. I spread one out, and instantly my mind passes into space. When the family appears, an hour later, I fold it up with a sigh of satisfaction. I have traveled far and made great plans for future voyaging."

Most maps are designed to present information of some particular kind. Railroad maps, highway maps, drainage maps, weather maps, air-navigation maps—all convey special information to the user. They are known as compiled maps, the particular information they are intended to convey being laid down on a base map, and they serve many very useful purposes.

However, these special information maps are simply two-dimension maps, picturing relative direction and distance. If a third dimension is added by means of contour lines to show elevation above sea-level they are converted into topographic maps, thus adding materially to their value and general utility. The most satisfactory method yet devised of representing relief is by means of contour lines. They were employed as early as 1728 by the Dutch engineer Cruquius to represent the bed of a stream, and a little later they were applied by Dupair-Triel on his map of France. A contour on the map represents a line on the ground, all points of which have the same elevation above the adopted datum, usually sea-level. Contour lines are drawn to represent regular intervals of elevation, which may range from one foot to 500 feet or more, depending on the nature of the country mapped and the size and scale of the map. The lines indicating steep slopes are crowded together; those indicating gradual slopes are far apart. In mountain areas they are numerous; in the plains they are few. In a region of rounded hills, they are smooth curves; in rough country they are angular and compact. Thus with a contour map in hand an experienced map reader visualizes at once and clearly the physical features of the country.

For the early development of topographic maps we are indebted largely to the military needs of nations. Inasmuch as a better understanding of the terrain for movement of armies was required than could be obtained from a two-dimension map, various methods by which the irregularities of the surface could be represented were employed. Thus we have early military maps representing relief by hachures, contour lines or shading. The fact that practically all European countries are at present covered by adequate and accurate topographic maps is the logical outgrowth of early military requirements. Indeed, in most countries of the present day topographic maps are made and published by their military departments. The United States, while recognizing the value of topographic maps in the national defense, utilizes them largely for the scientific study and inventory of its "tons of coal, barrels of oil and second-feet of water" and in the solution of the engineering, economic and industrial problems that affect the welfare of its people in which a knowledge of the "lay of the land" is vitally important.

In response to a report made by the National Academy of Sciences, Con-

gress created the U. S. Geological Survey in 1879 to coordinate under a permanent bureau the geographic and geologic surveys which at that time were being conducted in the public domain by four independent establishments. The new organization was charged with the duty of classifying the public lands and reporting on the geologic structure and mineral resources of the national domain.

To function properly as a scientific fact finder, the Geological Survey realized that a topographic base map which would accurately delineate physiographic and cultural details was a necessity. Accordingly, a plan was formulated and adopted to map the entire United States systematically in this way. The whole country was divided originally into quadrangular areas of one degree in latitude and longitude, to be mapped on the scale of 1:250,000, or about four miles to the inch. At the present time a quadrangle measuring 15 minutes each way, mapped on the scale of 1:62,500, or about one mile to the inch, is adopted as the standard unit for a general-utility base map of the greater portion of the country, except the mountainous and desert regions of the West, where a 30 minute quadrangle is the standard unit. Maps on these scales are being supplemented by base maps on the scale of 1:31,680, or half a mile to the inch, in reclamation, industrial and metropolitan areas where larger maps are indispensable for intensive engineering and city-planning studies.

This general-utility map, sometimes called the master map of the entire country, is being engraved and printed in sheets about 20 by 16½ inches in size, suitable for easy handling and filing. An indication of its popularity is the fact that nearly a million copies of individual sheets were distributed last year to the general public, to other government bureaus and to state or municipal agencies.

The very latest surveying instruments and methods are utilized in making this topographic base map. To prepare it specialized talent is necessary, trained in representing ground forms accurately on paper through the medium of contour lines, which are actually drawn in the field by the engineer.

Although this topographic base was planned primarily to serve the needs of the geologist in his researches and studies of the mineral resources of the country, to aid the hydrologist to gather pertinent information on the flow and utility of streams, on the occurrence of ground water, on the quality of water supplies and on the water-power resources of the country, and to assist in the scientific classification of the public lands, this informative type of map serves very many useful purposes in engineering, scientific and industrial investigations carried on by other government bureaus, state and municipal agencies, business organizations and private individuals. In the succeeding paragraphs are set forth a few examples of concrete and beneficial applications of these maps in the solution of varied problems.

Topographic base maps afford the geologist a medium through which he can make the results of his field investigations usable by others. They help him to solve fundamental regional problems and to interpret broad structural conditions in areas where coal, oil and gas exist. They make his task much easier in the search for potash, phosphates, copper, lead, zinc or other ores or minerals essential to modern industry. It is estimated that a first-class topographic base map saves at least 60 per cent. of the geologic investigator's time in his field work. This is especially true where large-scale base maps are available for detailed studies of rock structure in mineralized areas.

A great saving in highway construction can be effected if the availability

and quality of road-building material are known. A trained geologist engaged in work on road material can, with the aid of a topographic base map, locate new and better deposits of gravel, limestone, shale, disintegrated granite, sand or clay. Such a survey can be conducted in 25 to 50 per cent. of the time necessary where a topographic base map is not available. This is particularly true in the locating of limestone and shale quarry sites. The geologist can spot on the map those places where the elevation and topography favor the development of a quarry. He can determine the feasibility of haul from the quarry site to the project on which the material is to be used. Or he can, as was exemplified near Superior, Wisconsin, concentrate the search for a desired type of gravel in the most favorable localities in wooded areas by identifying on the topographic base map the topographic forms that typify gravel deposits. Such a thorough study of available developed and undeveloped highway material has produced a saving in the State of Wisconsin's highway-construction program of $231,000 in 1928 and $212,000 in 1929 on 240 miles of paving.

To the angler, topographic base maps have very interesting uses in lake regions. In limnologic studies a knowledge of the area, depth and elevation above sea-level of lakes is desirable. These data combined with an analysis of the water determine the presence and the quantity of plankton, bottom forms and other material on which various species of fish feed. The presence or absence of fish food has a direct bearing on the abundance of fish in the lakes.

In the settlement of controversies over state and private boundaries or in the preservation and determination of old boundary lines topographic base maps assist the courts in dealing fairly. In very old communities, in which settlements and titles have developed without regard to surveys and many natural monuments upon which descriptions of boundary lines and titles to land depend have completely disappeared, accurate topographic base maps resulting from fundamental field surveys are the medium through which it is possible to redetermine boundaries to accord with recorded titles.

Local authorities of to-day find maps just as useful for purposes of taxation as they were in Babylonian times. The valuation officer is able to make a fairer estimate of the value of taxable property if he has at hand topographic data that show the location of the property in relation to other tracts of land and give him authentic information with respect to its elevation and drainage and its suitability for agricultural or other purposes.

A state or county government can well afford to postpone the solution of any drainage or irrigation problems until exact topographic information in the form of topographic base maps is available. Any attempt to plan a drainage and irrigation system without such a map would be mere guesswork and costly to the taxpayer. The greatest obstacle to the agricultural development of the Gulf coast and part of the Atlantic coastal section is the lack of natural drainage. The success of local drainage districts has been limited largely by failure to attack the drainage problem on a scale large enough to embrace a sufficient area—a whole county or a group of counties—because exact topographic data were not available in advance.

The economic value to highway engineering of accurate topographic information is illustrated in the final location of a highway from LaFollette to Jellico, Tennessee. The best preliminary trial survey possible had been made by the state highway department, resulting in the location of a road 26.3 miles long. Later a topographic base map of a belt of country between these two cities was made, and a new highway location with

no grade over 6 per cent. was worked out. The new location was 7.3 miles shorter than the other, which meant a saving of over $200,000 in construction costs, and there was an additional saving of $2,000 in making the final location by having at hand the base map to direct the field party. With the physiographic features correctly delineated on a map of the belt of country through which he desired to project his road the highway engineer was able to consider his problem in a broad way and, like the geologist, to solve with ease a fundamental regional problem in a mountainous country.

In railway location the topographic base map finds its primary value as a substitute for reconnaissance in preliminary surveys. Instead of the usual method of reconnaissance, a set of topographic base maps, if available, is obtained and enlarged to a workable scale, and a study is then made of the most feasible layout. Profiles are carefully prepared from the contour lines and intermediate elevations are interpolated with remarkable accuracy, so that estimates of necessary earthwork, culverts, bridges, etc., can be compiled.

The great value to a state of a complete set of base maps of its entire area will be increasingly evident from year to year. The State of California has available a set of maps covering all the Sacramento River Valley and about 90 per cent. of the San Joaquin River Valley. During the past year the Division of Water Resources of the California Department of Public Works has carried on investigations at a great saving to the state with the aid of this set of maps, and recently it completed in a very short time the classification of the lands in these valleys. With the funds available a wholesale classification such as this could not have been made without the maps. They are indispensable and in constant use. In flood control, reclamation and river rectification they are the first maps to be consulted and generally furnish all the information necessary as to general location and carry the only available topographic information upon which to base preliminary studies.

In field investigations of the Public Health Service topographic base maps are of tremendous use in carrying on demonstrations of malaria control. They aid in laying out the most economical anti-malarial drainage schemes or in picking out the most advantageous places at which to carry on anti-mosquito investigations. Such work can be usually completed in a few weeks by the aid of these maps, whereas it is estimated that two years would have been required without them. In 1929 the Public Health Service was called upon to make a mosquito production survey of the eastern part of Massachusetts. Through the aid of topographic base maps the service was able to do its part of the work in less than a week. If these maps had not been available, one trained worker would have found it necessary to devote an entire season or else have failed in the work altogether. It is estimated that without the aid of such maps not more than one half of the area could have been successfully covered.

In planning studies of stream pollution and natural stream purification and interpreting the data obtained, topographic base maps are of great assistance. The value of such maps is appreciated where they are not available and less detailed and less reliable maps must be obtained from other sources. In the studies of existing sources of stream pollution affecting the public health they indicate the allocation of the population within and without the stream basins, the density of population per square mile in each drainage basin, the location and grouping of urban population having domestic sewage as the main source of pollution, the sections of the

basins which may be rural in character and in which pollution may be caused by surface drainage, the possible pollution from waste-producing industrial plants and the distances along water courses to sources of pollution. In the collection of hydrometric data for analyzing water from such streams, topographic base maps indicate the general topography in a drainage basin and give to the expert reliable data upon which to base an estimate of the rapidity with which run-off will occur from the different parts of the basin. The resulting surface erosion has a direct effect on the turbidity of the water and the chemical and bacteriologic analysis of samples. By the delineation of the swamps, ponds, lakes, reservoirs, etc., the maps assist materially in the interpretation of chemical and bacteriologic findings. Changes in the width of streams, the character of the stream banks and the flood plains, the position of waterfalls, dams, dikes, sluices and islands, the slopes of river beds and many other pertinent features are all represented by symbols on topographic base maps and are factors in the selection of points for collecting water samples for chemical and bacteriologic analysis. The maps indicate the location of railway and highway bridges from which samples may be collected, the proximity of communities and railroads to sampling points for shipping water samples and the location of probable sources of pollution above or below which sampling stations should be located.

Plant quarantine is established to protect the agricultural resources of the country and therefore affects the well-being of the whole people. In the recent campaign against the Mediterranean fruit fly in Florida, wherever topographic base maps were available (only about 8 per cent. of the state, or 4,700 square miles, has been adequately mapped) it was an easy matter to locate and plot the infested areas and plan prompt eradication measures. The U. S. Department of Agriculture in its plant quarantine and control administration has advantageously used topographic base maps. The accurate location of lakes, ponds, streams and highways, whether used or abandoned, and the representation of elevation by contour lines are particularly useful in its moth-control campaign during the spraying season. In mountainous and sparsely settled sections of the country certain methods of carrying on field work may be modified to conform to some peculiarity of the country as brought out on the map. In the campaign for the eradication of the pink boll worm the maps assist in locating canyons where plants related to cotton might grow and to trace out wind currents that carry the moth. Topography has a definite relation to temperature, wind and other climatic factors and to meteorologic conditions affecting the development and behavior of insects. Topographic base maps are used successfully in tracing the places where the Mexican bean beetle hibernates in the mountains at some distance from the bean fields. They are of great assistance in the study of bioclimatics, which relates to the general relation of climate to the distribution and abundance of insects. Bioclimatic areas can be readily outlined on topographic base maps without extensive field surveys. In the eradication of Texas fever among cattle topographic base maps have been invaluable in establishing a drift fence along the California-Mexico international boundary. Topography affects rainfall and other climatic conditions and thus has a bearing on the distribution and prevalence of various parasites of live stock, especially on the spread of eggs and larvae of parasitic worms. A good preliminary study of topographic conditions in infested areas can easily be made with the aid of these maps.

SOLID MATTER: WHAT IS IT, AND WHY?

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SOLIDS differ chiefly in the kinds of atoms of which they are composed and in the arrangement of these atoms in space. A study of what solids are is largely a study of the nature of these arrangements and the properties of the different kinds of atoms when in such arrangements. A study of why solids are, and in particular why the particular arrangements of atoms which exist do exist, involves primarily the study of the structures of atoms and the nature and magnitude of the forces producing combination between atoms. I shall therefore begin this paper by mentioning those known facts about the structures of atoms which are of particular importance in connection with the problem under discussion.[1]

It is generally agreed now that all atoms are composed entirely of protons—relatively heavy positive electric charges, and electrons—relatively light negative charges. The protons are all concentrated, with some of the electrons, in the small nucleus in the center of the atom. Those electrons not in the nucleus are distributed among various shells around the nucleus. (The sort of motions they are describing need not be considered for our purpose; for simplicity we may treat them as if they were in definite fixed positions.) The electrons which are of primary importance in holding atoms together in molecules and in solids are those in the outermost, or valence shell. These electrons we call "valence electrons," and designate everything inside the valence shell by the word "kernel."

The kernels of atoms may be classified according to their charge, or in other words, according to the number of valence electrons with which they must be surrounded to produce neutral atoms. (Table I.) Thus helium, neon, argon and the other rare gases have kernels with no charge at all (and so they have no valence shells); atoms of the alkali metals all have kernels with one unit of positive charge; atoms of the alkaline

TABLE I

KERNEL CHARGES OF SOME OF THE ELEMENTS

Kernel Charge	0	1	2	3	4	5	6	7
		H						
	He	Li	Be	B	C	N	O	F
	Ne	Na	Mg	Al	Si	P	S	Cl
	A	K	Ca					
		Cu	Zn			As	Se	Br
	Kr	Rb	Sr					
		Ag	Cd			Sb	Te	I
	Xe	Cs	Ba					
		Au	Hg			Bi		
	Rn		Ra					

[1] For a fuller treatment see Lewis, *J. Am. Chem. Soc.* 38, 762 (1916); Lewis, "Valence and the Structure of Atoms and Molecules," Chemical Catalog Co., New York (1923); or Huggins, *J. Chem. Educ.* 3, 1110, 1254, 1426 (1926); 4, 73 (1927).

earths have doubly charged kernels; boron and aluminum kernels have three plus charges; carbon and silicon four; nitrogen and phosphorus five; oxygen and sulfur six and the halogens seven. Osmium, in osmium tetroxide, and ruthenium, in ruthenium tetroxide, probably have kernel charges of +8.

A positively charged kernel attracts and sometimes holds valence electrons, the attraction being greater, in general, the greater the charge on the kernel. The magnitude of this attraction depends of course to some extent also on the size of the kernel, the distribution of electrons within it, the number and arrangement of other valence electrons around the kernel, etc.

Electrons in the valence shells of atoms, undoubtedly because each is spinning about its own axis and so is an elementary magnet, tend to pair off. Two single electrons in a valence shell seem to attract each other, but two pairs apparently mutually repel one another. This repulsion seems to limit the number of electron pairs which can be firmly held in an atomic valence shell. It is found that four pairs is the usual limit, although quite a number of cases of six- and eight-pair valence shells are also known, especially around kernels of small positive charge.

Although the tendencies of valence electrons to form pairs and of atomic kernels to be surrounded by stable valence shells—usually containing four electron pairs—are the major causes of combination between atoms, we should also bear in mind that even an atom in which these tendencies have been satisfied has some attraction between the positive parts of one atom and the negative parts of the other and in some cases as the result of the interaction of the magnetic fields surrounding each atom. These attractions, to which we may give the term "residual affinities" are often far from negligible.

Let us now consider the forces between like atoms, starting with those having a kernel charge of zero (the rare gases). It is evident that the only attractions between such atoms are the residual affinities just mentioned, and as these are weak, we should expect these elements to be gaseous except at very low temperatures. In the liquid state the residual affinities between the atoms are strong enough to hold them together within a small volume but not sufficient in magnitude nor sufficiently localized to maintain them in fixed positions relative to each other. On solidification we should expect the atoms to arrange themselves in some regular fashion with the atomic centers far apart relative to the size of the kernels. If so, the shape of the kernel should not be of much importance in determining the type arrangement, and it is therefore not surprising to find that the structure of solid argon[2], and xenon[3], as determined by X-rays, is that which would be assumed by any atoms of spherical symmetry—an arrangement in which each atom is surrounded by as many as possible (that is, twelve) of the other kind, commonly known as the cubic close-packed arrangements.

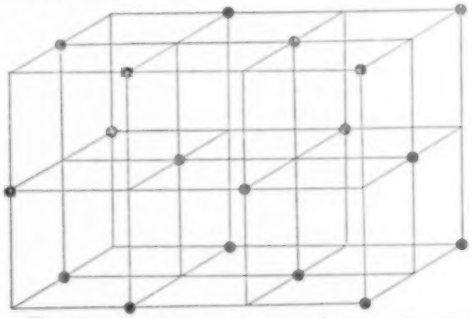

FIG. 1. A SMALL SECTION (ONE AND ONE HALF UNIT CUBES) OF THE FACE-CENTERED CUBIC OR CUBIC CLOSE-PACKED STRUCTURE. EACH ATOM IS EQUIDISTANT FROM 12 OTHERS.

[2] Except as otherwise indicated, crystal structures referred to are described in Int. Crit. Tables, I, pp. 338 *et seq.*

[3] Natta and Nasini, *Nature* 125, 457 (1930).

Fig. 1 shows the distribution of atomic centers in a small section of such a crystal. In the complete crystal, sections like this are set face-to-face, continuing the structure in all directions. The lines are of course only to aid in visualizing the spatial relationships. The "close-packed" nature of such an assemblage is most evident if one considers the arrangement of atoms in planes normal to the cube diagonal (Fig. 2).

FIG. 2. REPRESENTING A LAYER OF SPHERES IN THE CLOSE-PACKED ARRANGEMENTS. THE CENTERS OF SPHERES IN THE SECOND LAYER ARE OVER THE FULL DOTS. THE SPHERES IN THE THIRD LAYER ARE OVER THE SMALL OPEN CIRCLES, IN CUBIC CLOSE-PACKING, OR OVER THE SPHERES IN THE FIRST LAYER, IN HEXAGONAL CLOSE-PACKING.

Atoms of the halogens have kernel charges of $^{+}7$. The attraction for valence electrons is large, resulting in a strong tendency toward the formation of "complete" valence shells, containing four pairs of electrons. This tendency is satisfied, according to the theory of G. N. Lewis and according to the best experimental evidence, by the sharing of a pair of electrons between two atoms. (Fig. 3A.) In the halogen molecule thus formed the major tendencies of the atoms are satisfied, so the forces between molecules are relatively weak and the melting points and boiling points are

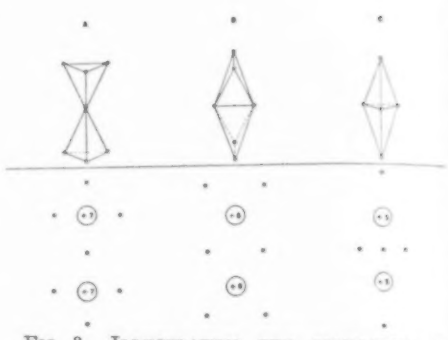

FIG. 3. ILLUSTRATING THE COMPLETION OF EIGHT-ELECTRON VALENCE SHELLS BY THE FORMATION OF SINGLE, DOUBLE AND TRIPLE BONDS, AS IN F_2, O_2 AND N_2. THE SMALL CIRCLES REPRESENT PAIRS OF VALENCE ELECTRONS.

low (compared with those of most of the other elements). Moreover, in iodine, the only one of the solid halogens whose crystal structure has been determined,[4] the atoms are in pairs and the distance between two atoms of a pair is less than that between two atoms in different pairs.

The oxygen kernel, with a net charge of $^{+}6$, also exhibits a strong tendency to obtain 8-electron valence shells. This tendency can be satisfied by sharing two pairs of electrons between two atoms, thus forming a double bond. (Fig. 3B.) Similarly, nitrogen kernels with charges of $^{+}5$, form N_2 molecules containing triple bonds. (Fig. 3C.) These O_2 and N_2 molecules do not have much attraction for each other, and we know that oxygen and nitrogen have low melting and boiling points.

Now it seems to be a general rule (first pointed out by Lewis[1]) that atoms of other than those in the first row of the periodic table do not readily form double or triple bonds. The tendencies of sulfur and selenium and tellurium atoms to obtain 8-electron valence shells can be satisfied however by the formation of rings, in which each atom shares electron-pairs with two others. Six-atom and

[4] Harris, Mack and Blake, *J. Am. Chem. Soc.* 30, 1583 (1928).

8-atom rings (Fig. 4) are possible without much distortion of the atoms or of the bonds between them, and such rings undoubtedly exist in sulfur vapor. The crystal structures of none of the forms of elementary sulfur have been completely worked out, but it is probable that in the ordinary forms there are molecular units of one or the other or both of these types.

In crystals of metallic selenium and tellurium X-ray studies[2] show that the atoms have satisfied their tendencies to

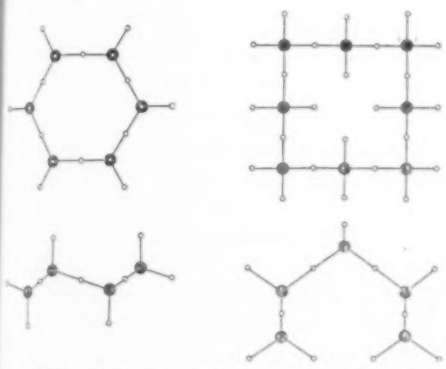

FIG. 4. 6-ATOM AND 8-ATOM RINGS, SUCH AS PROBABLY EXIST IN S_6 AND S_8 MOLECULES, SHOWN IN PLAN (UPPER FIGURES) AND IN ELEVATION (LOWER FIGURES). THE SMALL CIRCLES REPRESENT PAIRS OF VALENCE ELECTRONS. FOR SIMPLICITY THE STRUCTURES ARE DEPICTED AS THEY WOULD BE IF THE ATOMS WERE REGULAR (UNDISTORTED) TETRAHEDRA.

obtain 8-electron shells by forming spirals of atoms (Fig. 5) extending from one side of the crystal to the opposite side. Every atom (except those at the ends of the spirals) is bonded, by shared electron-pairs, to two other atoms in the same spiral. The distances between atoms in different spirals are relatively great and the forces between spirals relatively weak. These spirals furnish an example of what Lewis has called "continuing molecules," the size of which is limited only by the size of the crystal.

Phosphorus, arsenic, antimony and

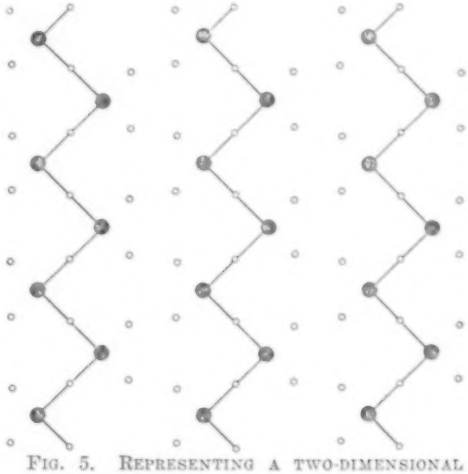

FIG. 5. REPRESENTING A TWO-DIMENSIONAL STRUCTURE ANALOGOUS TO THE STRUCTURE OF Se AND Te CRYSTALS.

bismuth, like nitrogen, have kernels, with net charges of +5. The first three of these form 4-atom molecules, probably having structures such as represented in Fig. 6, with only single bonds between the atoms.[5] These elements all also

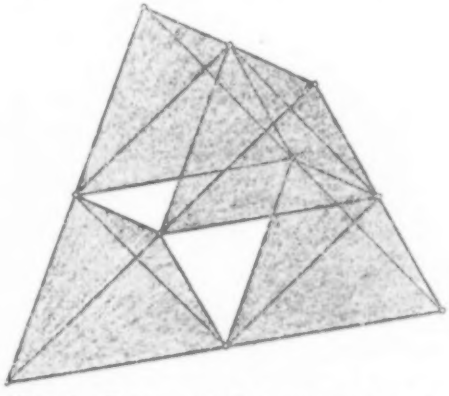

FIG. 6. THE PROBABLE STRUCTURE OF THE MOLECULES OF P_4, As_4, Sb_4 AND C_4^{----}. FOR SIMPLICITY THE ATOMIC VALENCE SHELLS ARE REPRESENTED AS REGULAR TETRAHEDRA.

[5] A tetrahedral arrangement of atomic centers has been found for the C_4^{----} ion in calcium carbide, Ca_2C_4, by Dehlinger and Glocker, *Z. Krist.* 64, 296 (1926). Moreover, white phosphorus, which gives P_4 molecules on dissolving or vaporizing, forms cubic crystals, as might be expected of tetrahedral molecules.

form[2] continuing molecules in which the atoms are in layers, with each atom bonded by single bonds to three others within the same layer (Fig. 7). The

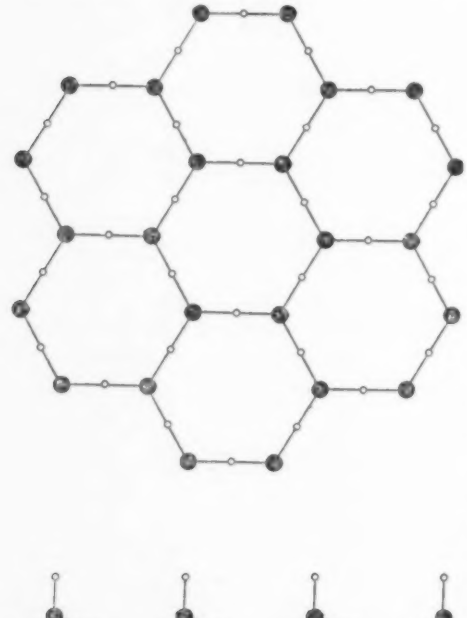

FIG. 7. A LAYER OF THE STRUCTURE OF THE RHOMBOHEDRAL FORMS OF P, As, Sb, AND Bi, SHOWN IN PLAN AND ELEVATION.

atoms within each layer are tightly bonded together, while the layers are held together only by much weaker residual forces.

Atoms such as those of carbon, silicon, germanium and tin, with kernel charges of +4, can obtain stable valence shells consisting of four electron-pairs at tetrahedron corners (in the absence of other kinds of atoms) only by forming three-dimensional continuing molecules such as that in the diamond crystal[2] (Fig. 8). Each atom throughout the crystal is bonded to four others.

Such 8-electron valence shells are not possible when all the atoms have kernel charges of three or less, for the number

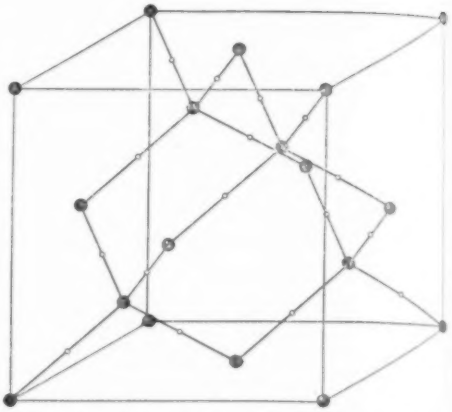

FIG. 8. THE UNIT CUBE OF THE DIAMOND CRYSTAL.

of electrons required to balance such charges is insufficient. With kernels having such small charges the attractions for valence electrons are relatively weak. The distances from atomic centers to valence electrons, and also those between adjacent atomic centers, are relatively large, and the arrangements usually assumed are the "close-packed" arrangements—in which each kernel is surrounded by twelve others (Fig. 2). In a number of instances, probably to give a more stable equilibrium distribu-

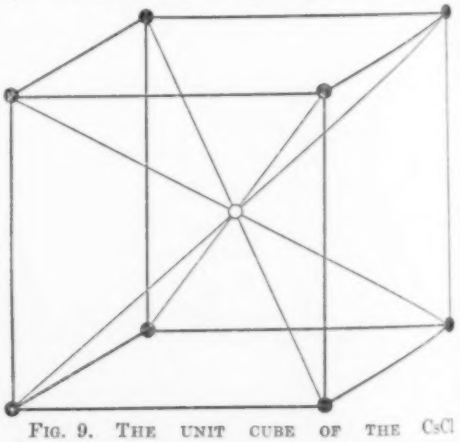

FIG. 9. THE UNIT CUBE OF THE CsCl STRUCTURE. THE CENTERED-CUBIC ARRANGEMENT, FOUND FOR A NUMBER OF METALS, IS SIMILAR, EXCEPT THAT ALL THE ATOMS ARE ALIKE.

tion of the valence electrons, the centered-cubic arrangement (Fig. 9), in which each kernel is surrounded by eight others, is found. The best evidence indicates that the valence electrons are in oscillation or rotation about equilibrium positions between the kernels, with several kernels around each electron and several electrons around each kernel. Whether or not these electrons are paired is still a moot question.

Let us consider now the structures of crystals of compounds. If all the atoms can obtain complete valence shells by sharing electron pairs between them, forming small molecules, such as CCl_4, SnI_4 and CO_2, the forces between these molecules will be quite weak, and liquid and crystal formation should take place only at relatively low temperatures. We should expect such molecules to persist as definite entities within the crystal, and that is found to be the case.[2] The exact distribution of molecules in the solid depends of course on the nature of the distribution of the residual forces between them.

Atoms with the larger kernel charges (6 or 7) sometimes completely remove electrons from atoms with small kernel charge (1 or 2), thereby producing ions. Each ion so formed has an attraction for ions of opposite charge. As a result of this attraction and of the mutual repulsion between like-charged ions, the ions come together in solid arrangements such as those of cesium chloride[2] (Fig. 9) and sodium chloride[2] (Fig. 10). In the former each ion is surrounded by eight of the other kind and in the latter by six. The cesium chloride structure is the one one would expect of ions of the same size having spherical symmetry or of non-spherical ions small in size compared with the distance between them; the existence of the sodium chloride type in which like ions form a close-packed assemblage, can be attributed to a considerable difference in size.

A still greater difference in size may be the chief factor producing the structure of Fig. 11 for cuprous chloride,[1]

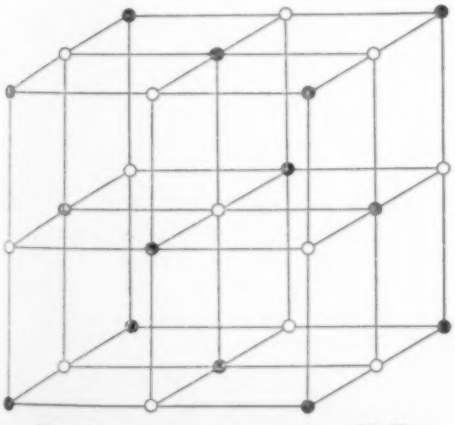

FIG. 10. THE UNIT CUBE OF THE NaCl ARRANGEMENT.

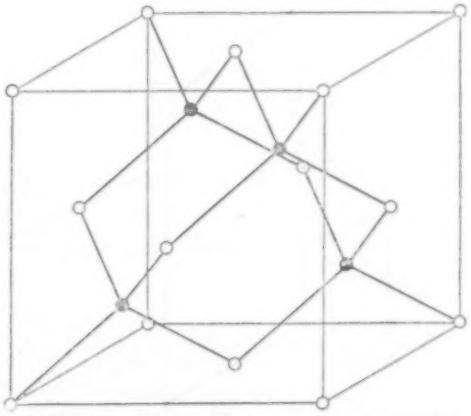

FIG. 11. THE UNIT CUBE OF THE STRUCTURE OF CuCl, ZnS AND MANY OTHER COMPOUNDS. FOR GREATEST STABILITY ONE WOULD EXPECT THE VALENCE ELECTRON PAIRS TO BE ON THE ATOMIC CENTERLINES, BUT MORE TIGHTLY BOUND TO THE Cl OR S THAN TO THE Cu OR Zn.

CuCl, and many other compounds, but it may also be that there is a definite tendency for the cuprous kernel—like many kernels of greater positive charge—to be surrounded by four-pair valence shells. This arrangement is like the diamond arrangement (Fig. 8) except that there are two kinds of atoms and that the valence pairs are much more tightly held by the chlorine kernels (charge +7) than by the copper kernels (charge +1).

Ammonium chloride, NH_4Cl, has two different forms of structure.[2] The one stable at higher temperatures has a distribution of ions like that in sodium chloride. That stable at lower temperatures has the cesium chloride type of structure. In both forms each nitrogen is surrounded tetrahedrally by four hydrogens. The low temperature form is particularly interesting in that each hydrogen is probably on a nitrogen-chlorine centerline, and may be considered to be bonded to both by means of valence electron-pairs. (See Fig. 12.)

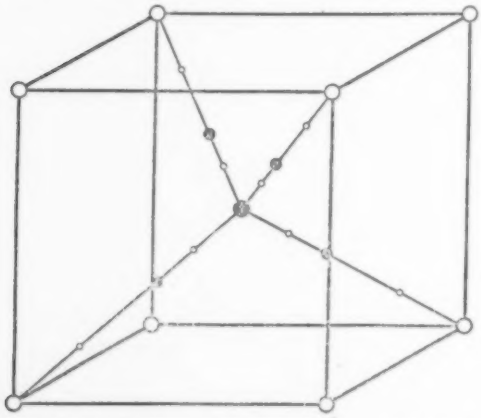

FIG. 12. THE UNIT CUBE OF THE LOW-TEMPERATURE FORM OF NH_4Cl. THE TETRAHEDRA OF VALENCE ELECTRON PAIRS AND OF HYDROGEN NUCLEI (THE SMALLER FULL DOTS) ARE ORIENTED AROUND THE NITROGEN AND CHLORINE KERNELS (THE LARGE FULL DOTS AND OPEN CIRCLES) IN SUCH A WAY AS TO GIVE GREATEST ELECTROSTATIC STABILITY.

Crystals of any of the compounds mentioned above can be pictured as being formed either from ions or from neutral molecules. The molecules, though neutral when considered as a whole, would be "*polar*," the more electropositive atoms (those with small kernel charge) having but one or two electron-pairs in their valence shells and the more electronegative atoms (those with large kernel charge) having one or more valence pairs which are not acting as bonds between atoms. The attraction between the kernels of the positive atoms and the lone pairs in the negative atoms, or, more generally, the tendency of each electropositive atom to be surrounded by electronegative atoms, and *vice versa*, causes the molecules to come together in the arrangements described.

Applying these ideas to the structure of ice, we see a reason for the structure[6] deduced from X-ray data. The molecule we may represent as $H:\ddot{O}:$ $\ddot{H}$. The attractions between the hydrogen kernels and the "lone pairs" in the oxygen

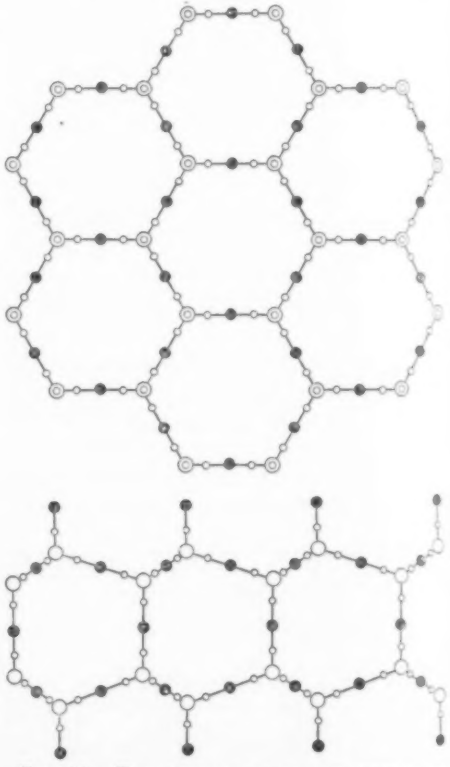

FIG. 13. THE STRUCTURE OF ICE, SHOWN IN PLAN AND ELEVATION. FULL DOTS DENOTE THE POSITIONS OF THE HYDROGEN ATOMS, LARGE OPEN CIRCLES OXYGEN, SMALL CIRCLES VALENCE ELECTRON PAIRS.

[6] W. H. Bragg, *Proc. Phys. Soc.* 34, 98 (1922). Barnes, *Proc. Roy. Soc.* A125, 670 (1929).

valence shells cause these molecules to aline themselves in such a way as to surround each oxygen tetrahedrally by four hydrogens, each of the hydrogens being midway between two oxygens. (Fig. 13.)

Another example is that of mercuric iodide,[7] $:\ddot{I}:Hg:\ddot{I}:$, which crystallizes in "layer molecules" in which each mercury is bonded tetrahedrally to four iodine atoms and each iodine to two mercury atoms. (Fig. 14.)

In ordinary quartz[8] it is found similarly that each silicon is bonded to four oxygens and each oxygen to two silicons, the whole crystal in this case being a single molecule. That both silicon and oxygen kernels (with four and six plus charges respectively) hold very tightly to the valence pairs between them is evidenced by the insolubility, high melting point and hardness of the substance.

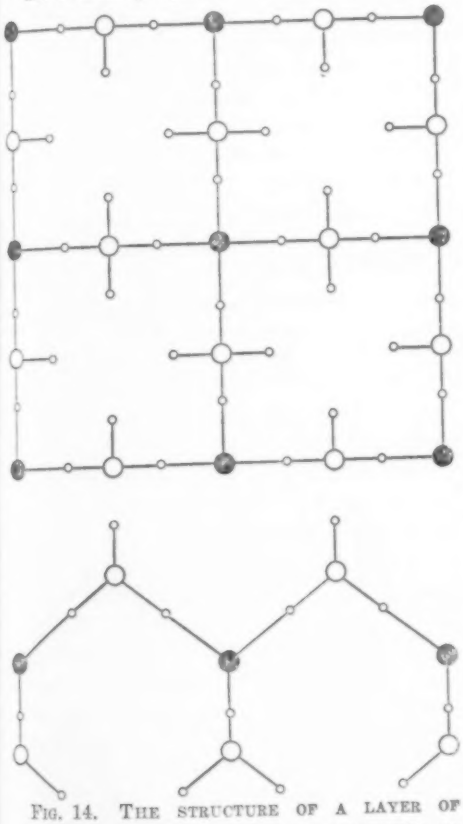

FIG. 14. THE STRUCTURE OF A LAYER OF ATOMS IN THE HgI_2 CRYSTAL, REPRESENTED BY PLAN AND ELEVATION. LARGE DOTS DENOTE Hg CENTERS, LARGE OPEN CIRCLES I CENTERS.

Up to this point I have discussed only the arrangement of atoms in certain molecules and in perfect crystals. I wish now to mention certain types of irregularity, with their causes and effects.

Some crystals posses such a structure that it is fairly easy for slipping to occur between adjacent planes of atoms in certain directions (*e.g.*, between the layers of atoms in the close-packed arrangements, Fig. 2), the relative arrangement of the atoms on both sides of the "slip plane" or "glide plane" being the same before the slip as after. This can not of course occur if the shift involves any breaking and remaking of tight bonds. If the forces between the layers which are slipping past each other are not strong enough to hold them together, or in the absence of slipping, if the forces between two adjacent layers are sufficiently weak, the plane between them is a cleavage plane. In some cases, as in the "layer molecule" crystals, I have mentioned—phosphorus, arsenic, antimony, bismuth, mercuric iodide—cleavage is very easy to bring about. In single crystals of the metals, glide planes or cleavage planes or both are the rule rather than the exception.

In the growth of a crystal there are sometimes two or more ways in which an atom can add to the crystal surface which satisfy equally well (or nearly so) the forces between it and other atoms. For instance, imagine a crystal of a metal in process of formation. (See Fig. 2.) After two layers have been

[7] Huggins and Magill, *J. Am. Chem. Soc.* 49, 2357 (1927). Bijvoet, Claassen and Karssen, *Proc. Roy. Acad. Sci.* Amsterdam 29, 529 (1926).

[8] Huggins, *Phys. Rev.* 19, 363 (1922). Lewis, "Valence, etc.", Ref. 1, p. 94. W. H. Bragg, *J. Soc. Glass Technology* 9, 272 (1925). Gibbs, *Proc. Roy. Soc.* A110, 443 (1926).

formed, the atoms in the third layer might place themselves either directly over those in the first layer or over the holes between the atoms in the first two layers. If the former, and the process is continued indefinitely, the atoms in each layer being directly over those in the second layer underneath, a crystal having the "hexagonal close-packed" structure results. If the layers are added so that the fourth layer is over the 1st, the 5th over the 2nd, the 6th over the 3rd, etc., the "cubic close-packed" structure is produced. If a crystal starts to be cubic-close-packed and then one layer "goes wrong," the subsequent layers however following the original scheme, a "twinned" crystal results, the whole crystal being symmetrical about the plane of twinning.

Another example of twinning (in a hypothetical two-dimensional crystal) is illustrated by Fig. 15. Imagine a two-

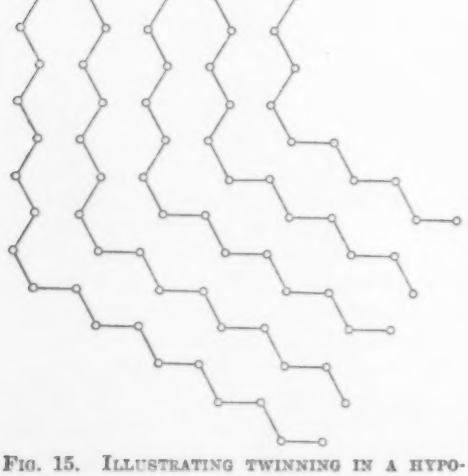

FIG. 15. ILLUSTRATING TWINNING IN A HYPOTHETICAL TWO-DIMENSIONAL STRUCTURE.

dimensional crystal growing regularly in the vertical direction. One of the atoms happens to add in the wrong place, all the primary valence forces and most of the residual affinities being quite as well satisfied as if this atom had gone where it really belonged. This out-of-place atom causes others (all in a certain row) to take up irregular positions. If the crystal then grows regularly again, a twinned structure such as that shown is produced.

In an ordinary metal there is a great deal of twinning. In fact the arrangement is probably usually more nearly like what we would get if we dumped a large number of shot into a box. Wherever there is twinning, however, any cleavage planes or glide planes not parallel to the twinning plane must come to an end at that plane. Hence gliding and fracture are much harder to produce in ordinary pieces of metal than in single crystals—that is, the latter are "softer." Gliding and cleavage can also be hindered to a large extent by the presence of small amounts of certain impurities, the added atoms serving to make the crystal planes irregular and to lock adjacent planes together.

Glasses differ from crystals in that there is no regularity throughout in the whole mass—although each electropositive atom is probably surrounded by electronegative atoms and *vice versa*. They differ from liquids in that each atom seems to be held by quite rigid constraints in or near a definite position of equilibrium. Being essentially different from both the crystalline and the liquid state (and also the gaseous state, of course), perhaps we should call the glassy state a "fourth state of matter."[9]

I wish to close with a brief consideration of the nature of wood. We all know that wood consists largely of cellulose fibers, between which and within which are water, resins and various organic and inorganic materials. The structure of cellulose has been the subject of speculation and research for many years, but

[9] *Cf.* Parks and Huffman, *Science*, 64, 363 (1926).

it is only recently that anything like a satisfactory solution has been attained. Studies[10] of cellulose by X-ray means show that the structure is one containing long string molecules (Fig. 16), the atoms in each string all being held together by primary valences. In this figure, the carbon atoms are represented by black dots, the oxygen atoms by circles. Hydrogens are not shown, but are attached to each oxygen except those in the rings and to each carbon not otherwise bonded to four atoms. Such a structure, although possibly incorrect in some details, accounts well for the physical properties of cellulose, its swelling —due to absorption of water—in directions perpendicular to the fiber axis, its chemical properties, etc.

Although it has not been possible to go very deeply into the subject in this paper, perhaps enough has been presented to give an idea of the sort of information which is being obtained nowadays in regard to the nature of matter and to give an indication of the marvelous results which are sure to follow further application of X-ray and similar methods to the study of such problems.

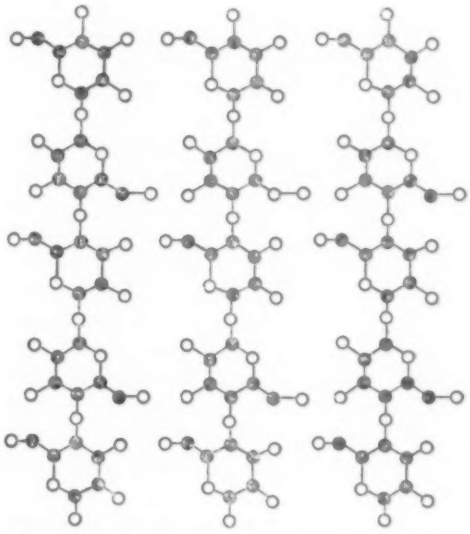

FIG. 16. REPRESENTING THE STRUCTURE OF CELLULOSE.

[10] Sponsler and Dore, "Fourth Colloid Symposium Monograph," Chem. Cat. Co., New York (1926), p. 172; *J. Am. Chem. Soc.* 50, 1940 (1928). Herzog, *J. Phys. Chem.* 30, 457, (1926).

SOME OBSERVATIONS ON BUTTERFLY MIGRATIONS

By AUSTIN H. CLARK

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GREAT multitudes of butterflies flying steadily onward in a definite direction after the fashion of the flocks of birds which with us pass south in autumn and return in spring, have often been reported. Indeed, in many regions these mass movements of the butterflies are so very striking that no one can fail to notice them.

The term migration commonly applied to these linear group movements of the butterflies is a rather unfortunate one, as it implies a comparison with the migrations of birds, with which they have little in common except that they are movements measurable in geographical terms.

Bird migrations are typically movements of a very definite nature from the breeding grounds to another region more or less remote and back again, usually by the same path. In the case of birds the round trip is completed several or many times in the life of each of the individuals, and furthermore the movement usually involves all the individuals of a species in a given breeding area.

Butterfly migrations rarely involve more than a portion, and often only a relatively small portion, of the individuals in any given region. So far as the individuals are concerned, the migrations are in one direction only, and so far as the species is concerned, there is seldom any definite indication of a return movement.

There are also other differences between the migrations of birds and the so-called migrations of butterflies—but there are also some curious correspondences.

The problem of the so-called migrations of butterflies is a very complex one involving a great number of diverse factors, both external and internal. The internal factors vary more or less widely not only in the different groups of butterflies but also in closely related species within small groups, and in seasonal or other alternative forms within a species. The nature and relative importance of the external factors vary with the differences in the habits and reactions of the different species, and of the forms within a species.

In some butterflies migration is a regularly recurrent, usually annual, phenomenon, while in others it takes place only occasionally. In some it is more or less characteristic of certain forms within a species but never occurs in an alternative form.

It is probable that many butterflies not usually so regarded are in reality migratory, traveling always as independent individuals and chiefly at night.

Most migratory movements among the butterflies seem to be traceable to three main causes—first, the natural propensity of a gregarious species to wander; second, the inability of the males of certain species to live together if their number in a given area exceeds a more or less definite maximum, and third, the destruction of the food plant, or some other adverse circumstance affecting a more or less extensive region.

Observations made within the past few years in and near the District of Columbia seem to have a definite bearing on the origin of the migratory movements of certain types of butterflies.

The milkweed butterfly (*Danais*

plexippus) is normally not very common in this region at the present time, six or eight, perhaps as many as a dozen but seldom more, being seen in a large field at the end of the season. It was unusually scarce in the dry summer of 1930. On September 15 in the extensive meadows west of Cabin John only four or five were to be found.

On September 16 there was a heavy shower in the afternoon. On September 17 these butterflies had enormously increased in numbers, and those present in the meadows were without exception quite fresh; furthermore, by far the greater part of those captured were males. A visit on the following day showed this insect to be still more numerous, outnumbering all the other kinds of butterflies combined, while of those captured a slight majority were fresh females.

The appearance of great numbers of butterflies after a rain is a common and striking phenomenon in the tropics, where I have observed it in Venezuela, but it is not often noticed so far north as Washington. The name "storm fritillary" sometimes applied to this butterfly in the country may refer to its sudden increase in numbers after heavy rains.

On September 17—the day of their first appearance in large numbers—the individual butterflies were more or less evenly distributed over the fields, feeding everywhere on the goldenrod and also on the few and widely scattered thistles. On the next day (September 18) conditions were about the same, but sometimes as many as four or five would be seen about a single thistle.

On the succeeding day (September 19) it was noticed that the butterflies had to a certain extent become gregarious. They were no longer evenly distributed over the fields, but were to be found in more or less widely separated areas where, for instance, from half a dozen to a dozen would be feeding on the goldenrod in a space ten or fifteen feet square, or from six to ten would be seated on the heads of a large thistle with others on the nearby goldenrod. While in places two or three could be taken in a single sweep of the net, there would be none on the goldenrod for two hundred feet or more between the little companies of well-separated individuals.

These little companies were constantly on the move. But they always moved as individual butterflies and never as if the company were a unit. A butterfly would start up and fly for perhaps fifty or a hundred yards, finally settling on a goldenrod some distance—five or ten feet perhaps—from another individual. Then a third would settle near these two, and pretty soon another little company would be formed. Sometimes on being frightened a whole company would move off in the same general direction, but the individuals always seemed to scatter more or less. The procedure seemed to be, for the most part at least, a continuous forming, breaking up and reforming of small and loose aggregations of independent individuals. But it was noticeable that the majority of the butterflies would keep within a certain area which was continually shifting north or south along the belt in which the goldenrod was most luxuriant.

While most of the butterflies flew only a foot or so above the tops of the goldenrod, one was seen to drop from a great height, being first observed on the downward path about a hundred feet above the ground.

On the following day (September 20) further changes had taken place. As we reached the field at half past two in the afternoon we saw, within a few minutes' time, four butterflies from twenty to one hundred feet or more above the ground headed southward but drifting westward toward Great Falls

before a moderate wind. Some minutes later a butterfly which rose five or six feet away and which could not have been much frightened mounted high into the air and departed in the direction of Great Falls. These traveling butterflies were seen in the western end of the field, where the goldenrod is stunted and scattered and is not visited by the butterflies.

In the more luxuriant portion of the fields the insects were more restless than they had previously been. They wandered about more and did not remain so long on the flowers. Also their numbers had decreased considerably. Most of them were now gathered into two flocks, a small one of two dozen or so individuals in the northern half of the field and a very much larger one in the southern half. Both flocks were more compact than any which we had seen previously, and as many as four butterflies were often to be seen on a single goldenrod.

The restlessness of the individuals in both flocks was quite apparent, for they frequently shifted their position by flying a few feet. The increased sociability was also apparent. Whenever an individual which was flying over the field alighted we always found that it had alighted near another, or near several. The butterflies could not, however, be decoyed by a dead individual, as is so easily done in the case of the pierids and the swallowtails.

In the later part of the afternoon individuals were seen flying toward one or another of the small trees scattered about the fields. Examination of the trees, however, disclosed only a single butterfly clinging to a leaf about four feet above the ground. But we left before the time these insects usually retire for the night.

On September 24, just a week after their first appearance in numbers in the fields, these butterflies were noticed at various places in the city of Washington, even in the business district. On the following day they were rather frequent about the city, always flying in a leisurely and aimless manner at a height of usually from eight to ten, but sometimes from fifty to a hundred feet or more above the ground. They remained frequent in the city until well into October.

On September 26 another visit was made to the Cabin John meadows. In the northern half of the main field there were a few scattered butterflies feeding on the goldenrod—perhaps a dozen were seen in all. This is but little, if any, in excess of what would be expected at this date in a normal season. Half a dozen of the butterflies were caught. One was freshly emerged, with the violet iridescence at the maximum brilliance, and the others were all fairly fresh—two or three, one possibly four, days old, judging from the condition of the iridescence on the fore wings. Certainly none of them had been on the wing for as much as a week.

It was rather late in the afternoon and the insects were getting ready to spend the night. Those in the northern half of the field simply hung from a goldenrod or aster or one of the upper shoots of some other herbaceous plant as they always do when engaged in intensive feeding.

There were none of these butterflies in the southern half of the field, but an examination of a grove of trees south of the field disclosed two which were flying about among the trees in a desultory sort of way and occasionally perching on the under side of small dead branches eight or ten feet above the ground.

It was apparent that all the butterflies which had emerged on September 17 and 18 had left the fields, with the possible exception of the two seen in the adjacent woods, though these were very likely younger. So far as these fields

were concerned the unusual abundance of this species was a thing of the past; conditions had returned to normal.

A peculiar fact in connection with the appearance of this butterfly in the meadows beyond Cabin John is that in these meadows its food plant is not to be found. The occurrence of this insect in great numbers in areas wholly devoid of the food plant has previously been noted. It would seem that immediately upon emergence the butterflies betake themselves to a locality abundantly supplied with suitable flowers, where they may gorge themselves with a minimum of effort.

There is nothing in these observations that shows any departure from the normal habits of this butterfly as it occurs throughout the season. The adult life is divided into two phases, a period of intensive feeding during which no sex instinct is manifested, and a longer period of extensive wandering apparently followed by reproduction, during which feeding is relatively infrequent.

The flight of this butterfly is always leisurely and more or less direct, contrasting strongly with the highly irregular and angular hurried flight of nearly all our other butterflies. The males display little or no interest in each other, and the individuals are always to some extent sociable. Males and females occur in equal numbers, and the habits and the flight of the two sexes are practically identical. This species is particularly fond of flying along the sea coast and along rivers at all times, and on any day throughout the summer wherever it is common individuals may be observed flying in a leisurely manner at a great height. Over water the flight is more rapid and direct than over the land, and the wings are moved continuously.

If the multitudes of these butterflies at Cabin John were developing just as the same number of individuals scattered throughout the summer would have developed, it becomes evident that the so-called migrations of this butterfly are really nothing more than the collective expression of the normal habits of each of the individuals taking part in the migration. A very large number emerging from the pupa at the same time naturally engorge themselves together and then reach the traveling phase of their adult life simultaneously. So we see in the air large numbers together instead of merely isolated individuals. The appearance of the milkweed butterflies in swarms means simply, I believe, that something has occurred which has caused large numbers to emerge at the same time.

The direction taken by these swarms in a migratory flight is usually more or less directly toward the south, and this is especially true in the central portion of the continent, where they are most conspicuous and most frequently observed. But they do not always go south. Two migrations have been reported from the vicinity of Washington. In one the butterflies were flying south across Chesapeake Bay in the face of a stiff breeze, and in the other they were flying north with the wind. Those that we saw were going west with the wind.

It is most unlikely that the southerly direction of most of the migrations of this insect which have been reported has more than a coincidental relation to geography. It is far more likely that it is merely a function of the prevailing wind plus the local geographical features, especially rivers and the sea coast. The migrations of this butterfly are probably mere aimless wanderings having their origin in the natural wandering habits and the tendency to fly in a straight line inherent in each individual, and taking their direction from the prevailing late summer or autumnal meteorological conditions.

There is no real evidence of a north-

erly migration in the spring. In the early spring this butterfly is singularly inconspicuous. The worn and faded individuals fly very near the ground and are easily overlooked. They have been reported, however, from as far north as this insect is really common in New England. Furthermore the first brood appears in June at approximately the same time in New England and in the vicinity of Washington, which would scarcely be the case if they or their parents were immigrants into New England. The truth seems to be that, although most of them die during the winter, throughout the region where this butterfly is common a few survive and these survivors from the preceding year give rise to the next summer's population.

It is interesting to note that the abundance of the milkweed butterfly in eastern Massachusetts and southeastern New Hampshire in the autumn of 1888, just as the abundance in the vicinity of Washington in 1930, followed a summer in which the insect was unusually scarce.

Another type of butterfly migration seems to originate in the inability of the males of certain species to live together in a given area if their number exceeds a certain maximum.

Familiar to every one in late summer is the sight of a shrinking puddle surrounded by a muddy patch which is enlivened by a greater or lesser number of butterflies usually grouped in little companies, each company as a rule including butterflies of only a single kind, or at least of only a single color. The most conspicuous and most characteristic puddle butterflies in the more or less immediate vicinity of the District of Columbia are all pierids—*Colias philodice, Eurema lisa, Catopsilia eubule* and *Eurema nicippe*.

In connection with puddle butterflies it is noticeable in the first place that they are all males, and in the second place that they are all freshly emerged. It is frequently observed that on the appearance of a new brood the males are first seen in numbers about the puddles, later becoming common in the fields.

The occurrence of puddle butterflies seems to bear little relation to the amount of available water. In a normal year puddle butterflies will collect in numbers shortly after a rain when there can be no question of a sufficiency of water in the fields. On the other hand, in the exceptionally dry summer of 1930 when the numbers of all the butterflies were greatly reduced, the puddles and muddy patches in the vicinity of Washington were entirely deserted—not a single example of even the commonest of our puddle butterflies was to be found about them.

The true explanation of the puddle butterflies seems to be that they are young males from overpopulated areas in which they are incessantly tormented by other males and from which they escape to more peaceful surroundings. Requiring water, they naturally resort to the puddles, about which, in the absence of the rivalry excited by the presence of females, they fail to develop their usual pugnacity and instead become gregarious, flocking with others of their kind or with males of several kinds until they become fully mature, when they either return to the field from which they were originally driven or, remaining more or less gregarious, wander away.

The appearance of puddle butterflies —at least among the pierids—seems always to be evidence of an excess in the number of individuals of the species concerned in any given area. It is primarily evidence of a growing pressure of population—that is, of overcrowding.

Many, perhaps most, of the young males seen about puddles are only temporary exiles, returning to the fields when they have sufficiently matured and as the older males die off. But it is

quite probable that many of them would be unable to find a place for themselves in the fields and would therefore be permanently exiled. Such males would be very likely to wander—the males wander in any case—and in their wandering they would presumably fly in a more or less straight line against the wind, which is the usual habit of the individual males of our common species when simply traveling.

It is a reasonable assumption that surplus males of our two local pierids most given to migratory flights—*Catopsilia eubule* and *Eurema lisa*—would normally wander away, flying primarily against the wind. Being gregarious and very readily decoyed, even by crude paper imitations, other surplus males would tend to join them until finally a considerable number would be assembled in a loosely gregarious swarm. The nucleus of such a swarm might come from puddle butterflies, from exiled males in any area, from persecuted males still in the fields or from all three sources. Elimination of surplus males may take place when, so far as we can see, there is no actual evidence of overcrowding in the fields, especially in the case of such large, powerful and very active species as *Catopsilia eubule*.

The migrations of the pierids of the types corresponding to our *Catopsilia eubule* and *Eurema lisa* seem to be nothing more than the end-product of the natural process of the elimination of surplus males.

Much has been written regarding the southerly late summer and autumnal migrations of *Danais plexippus*, but little has been said of the northerly migrations of *Catopsilia eubule* which from time to time take place at the same season and in the same regions in the coastal area. As a concrete instance of migrations in opposite directions taking place simultaneously, I may say that in the very field where I observed *Danais plexippus* going west with the wind I have seen the males of *Catopsilia eubule* flying high and very fast eastward against the wind.

If the migrations of these butterflies were anything more than relatively simple responses to the meteorological and other physical conditions—that is, if they served any purpose beneficial to the individuals taking part in them—we should scarcely expect to find two primarily tropical butterflies migrating in opposite directions in the same place simultaneously, especially north and south.

The solution of the problems connected with the migrations of butterflies lies, I believe, in an accurate and detailed knowledge of the normal sequence of habits of both sexes of the species involved—in the case of dimorphic or polymorphic forms of both sexes of each of the forms—from the time of emergence from the pupa until death; of the real or apparent changes in the normal habits induced by overcrowding or by the destruction of the food plant; of the relations of the individuals of a species, particularly the males, to each other and to related species in the same region, and of the relations of the individuals of a species to the meteorological and geographical environment.

MENTAL DIFFERENCES AND FUTURE SOCIETY

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LIBERAL thinkers of the eighteenth century believed that with education free to all a great leveling of social inequalities would result. The cry of the times was for schools and popular education. Outraged by the evils of aristocracy and the abasement of the masses, the theorists of revolution in France, America and England advocated more and sometimes better education. From Rousseau to Noah Webster voices called for the diffusion of learning in the interests of greater social equality.

In their drive for popular education as a means of realizing political democracy, the eighteenth century liberals concerned themselves little with educational details and courses of study, striving first for the open door; and if the founding fathers knew how widely human ability to learn varies they said nothing about it. Common observation told them that there were men foolish and men of talents, but the shadow of the IQ had not fallen across the page in those days. Give society a popular educational system, thought they, and the hierarchy of privilege would crumble. Illiteracy marked a caste; the essentials of knowledge purveyed through the schools would give power to the masses.

To us it is interesting that differences in human ability entered so little into the discussion of the adequacy of the people to maintain democratic institutions. Without education the people were felt to be unfit for self-government; but that with education they might still be lacking seems not to have occurred to any one. It has remained for us to realize, in a time of the widest extension of educational opportunity, that there exists a range of mental ability that offers some very hard nuts to crack for exponents of democracy. The slump in democracy has coincided with the findings of intelligence tests.

With findings such that he who runs may read, there is not much doubt left about how we differ, from one end of the curve of intelligence distribution to the other, and we have discovered "that the number of people of relatively low intelligence is vastly greater than is generally appreciated."

Abundant and convincing is the literature of mental tests, and essential facts outside the pale of controversy give pause in social philosophy. Consider how widely we differ:

100,000,000 PERSONS		IQ
250,000	"Near" genius or genius	140–up
6,750,000	Very superior	120–140
13,000,000	Superior	110–120
30,000,000	High average	100–110
30,000,000	Low average	90–100
13,000,000	Dull	80– 90
6,000,000	Borderline	70– 80
750,000	Moron	50– 70
250,000	Imbecile and idiot	50–down

(*Based on data from Sandiford*)

With so many persons in the lower groups it must be that we are surrounded by "a number of people of relatively low intelligence." Carlyle said that the population of England was thirty millions, "mostly fools." A lawyer who looked at the foregoing table said he had always supposed there were a great many more morons than there are. Yet most of us who face the table are probably brought to a realization that from our youth up we have tended to idealize society, and are compelled to readjust our appraisals downward. Even if we plead guilty to a tendency to designate as morons persons we dislike, or who differ from us, we are yet scarcely prepared for "this mass of low

level intelligence." The upshot is that probably most of us are depressed, not to say unsettled, by considering the evident distribution of native ability in mankind.

Knowledge of range of ability will of course have repercussions upon theory and practice in government, upon education, literature, journalism, the theater and propaganda and advertising. For good or ill, use will be made of the accepted facts of intelligence, and exploitation and philanthropy will not escape their influence. We shall simply not be able to think as we used to think, when once the fact of mental range is burned into consciousness as an ever-present datum. The revolution in our thinking will be like that following the doctrine of evolution or the Copernican theory. To-morrow will not be as yesterday; dreams of human perfectibility and equality go glimmering, when we fear that half of the people can be fooled all the time. How swift the reaction to the new knowledge, witness the uncanny appropriation of a new province of low level suggestibility by propaganda. Until the fuller resources of gullibility had been probed by daring pioneers of popular psychology, no one claimed that you could get away with murder. The mind of the multitude has become a more real bonanza than in the days of Phineas Taylor Barnum, whose horrid estimate that a "sucker" is born every minute appears somewhat too low, by a rough calculation employing terms as informed as possible with the spirit of the great showman.

Our attitude toward the foolish we shall change, even as we have changed our attitude toward the insane and the sociopath. We have somehow commonly felt righteous when denouncing "fools." The fools have had the awfullest time, and all without their fault; they have been fair game for ages. The psalmist and the proverb maker, the satirist and the pedagogue all took their flings at the mentally short or plied ferules and adjusted the dunce cap. This is not the place to go into the harrowing tale of the social cannibalism that claimed the person of low IQ throughout the centuries, but the thought is ventured that the popular attitude towards the lower brackets of mentality has been no more justifiable scientifically than would be imprisonment on a charge of red hair or capital punishment for inheriting a Roman nose as a structural feature of one's own countenance. For humility's sake, let us reflect that intelligence is relative; if we encountered a race who could master geometry in an evening we should all be morons. The fool has been in no position to defend himself, and as a result has of course been unjustly blamed. Though many old doctrines and practices, escape devices in the interests of our own comfort, have been given up, the fool-baiting complex dies hard. Great poets, like Milton and John Dryden, did not hesitate to lambaste other persons for lack of intelligence; even the pulpit echoes scorn for the mentally deficient, whose handicap is as biologically reputable, no matter how inconvenient, as, at least, is the vermiform appendix. Ultimately the fact of mental range will be accepted with emotional equanimity, no matter what else happens.

Much may happen. While theorists are reconstructing their views of man as made, the affairs of the day go forward in the general direction of lines of least resistance, and the findings of mental tests are scarcely a step ahead of the unfolding of a daily record rich with items of practical application. Rates are what the traffic will bear; various and sundry pressures are made nicely correspondent to levels of intelligence; institutions and business do in a way hold the mirror up to nature. While there is enough uncertainty about intelligence in individual cases to keep up

excitement, in a rough way what happens is a measure of what the audience is adapted for.

Now "the blunt person is characterized by huge tolerance of absurd contradictions." He sees no absurdity in a reference to a road to town that is all the way down hill there and back—and gives himself to the instalment plan. He reads believingly that western New York State apples supplied the table of Queen Elizabeth, and accepts his party platform, and votes as usual.

Failure to note significant omissions reveals the deficient mind. Show to a mentally deficient person the picture of a wheel with the hub missing and he will not be conscious of the omission; with him there is no adequate sense of the completeness of evidence, no critical faculty at watch for essential elements. The trait in question prevails among the lower levels, mentally, of the consuming public, a fact taken advantage of by the advertiser who profits by leaving things out of the copy, leaving, as it were, the hub out of the wheel and inducing the credulous to think they are getting a wheel entire. An advertisement which, no compliment to me, reached me through the mails offered colored reproductions of notable pictures at small cost, but failed to declare how many reproductions would be sent for my money and gave no information on their size. If the reproductions had been only the size of postage stamps the buyer would have had no case; he would have been "stung." A man told me this afternoon how he had bought stock in an oil well, to find out later that an oil well will run dry after about a year. When he bought the stock he failed to note the time factor in an oil well's production.

Repeating the thought of a passage is a test of intelligence; according to fulness and certainty of restatement is intelligence disclosed. How often are the very words from one's mouth garbled immediately within hearing. The fine art of accurate reporting does not flourish among the lower IQ's, a fact that accounts for the vast jungle of ill-founded rumor and sloppy newsiness in the daily run; conjecture is converted into positive assertion; speakers are misquoted, scandals invented.

In the defining of abstract words mental status is indicated, which terms are derivatives from experience and represent the essence of meanings. It is notorious how ill defined by masses of the public are such terms as religion, evolution, patriotism, democracy, temperance, socialist, anarchist, agnostic, Republican and Democrat. And "this mass of low level intelligence is an enormous menace to democracy unless it is recognized and properly treated."

The dissected sentence is a familiar device in the literature of mental tests. A bright child is capable of taking a look at the words, "A defends dog good his bravely master," and of straightening these out into a sentence; the bright child would, without waiting to be asked to organize the words, feel that something was wrong in their sequence. On the other hand, the very dull would be unable to get them right, or would possibly gloat over them with a sensation of recondite lore. It would be invidious to cite examples from books and publications, some of which achieve circulation, in which actual, definite, tangible and unequivocal meaning is about as much present as such as in the dissected sentence before its reformation.

The giving of differences and similarities is a touchstone of intelligence. Not much matters with those of low intelligence; they note differences slightly and have not the meticulous perceptions of quality of the mentally alert. The nice distinctions out of which spring literature and science are obtusely noted or wholly unperceived; thus, in society afflicted with extensive moronism, Christianity and church membership are synonymous; no distinction is made be-

tween real and nominal wages; education and schooling are the same thing; agrarian and industrial feudalism, chattel and wage slavery go unsuspected of identities, while exactions for private profit and taxation for social purchasing arouse reversely suitable sentiments. The debunking process which has attained magnificent proportions in our decade simply witnesses to the extravagant lengths to which such simplicities have run us.

Look where you will and consult any type of mental test, and the net result is an intensified conviction of the massive aggregate of mentality in the lower groups, correlated products of which are in daily evidence. Quack doctors and clerical pretenders ply their trades; sucker lists are compiled of interminable proportions; words rather than ideas count; political corruption and crime glorification obtain; silly notions win silly people in the rhythmic raids of fashion; there are: noise, jazz, speed, war and the man who would walk a mile for a brand. True, for every man, woman and child with IQ below 100 there are a man, woman and child with IQ above 100; but here consider those below the line, among whom is the "typical moron":

> Graduate of a small but accredited high school. Spent five years to secure fifteen units. First year's work in university went poorly. Found to have mental age of about twelve and one half years. Good athlete. Good penman. Well dressed. Excellent manners. Entered a Greek letter fraternity. Father a banker. Mother apparently a superior woman. After K was dismissed from the university he was glad for "he could never learn books anyway." Good automobile driver. Memory span short. Unable to reproduce correctly simple geometrical designs. Could not imagine or think out new combinations of forms and of objects. Lacked resourcefulness and ingenuity. Unable to pick out or explain simplest kind of absurdities. Deficient associative bonds. Unable to find words of the same or analogous meaning, or to pick out essential likenesses and differences.—From "General Introduction to Psychology" by Griffith.

While such extremes and variety of intelligence have always been, outcomes under modern conditions must be awaited with interest. Knowledge increases the power of the dull, but multiplies disproportionately the resources of the superior; science means something directly to the lowly, but it gives unprecedented power to the gifted. As knowledge grows from more to more a wedge progressively separates the social fates of persons at different levels of native ability. Two illiterates of contrasting abilities would upon learning to read be still more different. Moreover, the remotenesses and complexities of modern commercial and industrial control baffle the lower orders of mentality, presenting nothing tangible as adversary. The manly art of economic self-defense through direct dealing passes when mergers and big business dominate. Economic manipulation governed by relatively high intelligence can be more persistently and hopelessly oppressive than face-to-face imposition. The bigness and inscrutability of manipulative processes leave the lower mentalities badly off for self-help. Advanced technical education means additional leverage against the mentally less endowed. A fact that our fathers did not see is that free schools do not remedy native differences of capacity. Says Pintner in "Educational Psychology," p. 144:

> Thus a child with an IQ of 80 is unlikely to be able to complete the eighth grade successfully. Such a child ought to be given practical vocational training in the last few years of his school life so that at the age of fourteen he may be in some way prepared for his future work in the world. A child with an IQ below 90 will probably derive little profit from the ordinary high-school course. Children with IQ's between 90 and 100 will probably profit from some of the more abstract work. To grasp the symbolism, understand the proofs and make the generalizations required in algebra probably requires a minimum IQ of 110. It is doubtful whether children with IQ's below 110 should be advised to take the customary course at a liberal arts college.

Paternalistic changes in the school system looking toward special care are implied in the new knowledge of mental differences; from limitations of ability an accommodation of schools must follow. Indeed, the gearing of instruction to mental status is an ideal of teaching, and accordingly we should expect that junior colleges, vocational high schools, trade and continuation schools and special classes would reflect the discovery of the extent of mental differences.

In other fields than education, readjustments will occur in view of awareness of the persistent contrasts in human ability and the amount of low level mind. As suggestive of what may take place recall the accommodations of journalism to progressive ascertainments of the true character of mentality at the lower levels, ranging from the original yellow journalism to exhibits on the news-stands to-day. As to the "fool-proofing" of machinery, one might question whether it can proceed much farther, or whether assistance can go much beyond that rendered by telling one to "cut on this line," when facing the problem of opening a mere box of breakfast food. Our high-grade moron was an expert driver of the automobile, proof of the extent to which shortage of intelligence was provided against. Influenced by the findings of mental tests it seems probable that the operation of all sorts of machines of popular use, and participation in travel, commercial transactions, funerals and recreation will be made easier and less burdensome on attention and thought.

The climax of our interest lies, however, in the effects of the fact of mental range upon social and governmental policy. Will not accommodations necessarily be made there? Is not Mussolini perhaps a man who has peered into the sociological beyond, divining and capitalizing the truth of human differences? May not the great Russian experiment be soundly cognizant of the range of capacity? May not the political philosophy of the future be based squarely upon the recognition of the great mass of low level intelligence even as our early democracy was based upon the dogma of essential equality?

How, let me ask, can the 30,000,000 IQ's first below 100 compete successfully with the 30,000,000 IQ's first above 100? How will the 13,000,000 dull, dull as God made them, fare in a struggle against the 13,000,000 superior? Picture the scene with 6,750,000 borderline folk and their associated morons pitted against 6,750,000 of the very superior. Last scene of all, 250,000 imbeciles and idiots in every 100,000,000 of population as an antithesis to 250,000 of the brightest minds that ever flashed.

Will paternalism, as a reaction to exploitation under modern controls, to competition that can have but one outcome, be ushered in? It would mean oversight, maintenance, management and protection, and also imply a degree of disregard for what dependents think. Will not realization of the amount of moronic intelligence speed us on the way to paternalism?

The answer is indicated by various significant trends. The movement for old age pensions, the rise of the theory of high wages as a general economic benefit at a time of inefficient labor organization and of the "yellow dog labor contract," the assumption under President Hoover of superior-class responsibility for unemployment, the dole in England, the giganticism of life insurance, the plight of the farmers, who have failed to help themselves, the rise of large-scale philanthropy, the frequency of failures among small-business men, and the victorious chain store, do, taken together, attest to a tendency toward social reorganization on lines reflecting mental caste. With the ripening of institutions and the perfection of economic strategies, assuring steady increase of disproportionate benefits to the upper levels of intelligence, it can be only

through policies determined at the seats of power that, for example, in the United States, the farmer is not made a peasant or exhaustively exploited and put on a dole.

The potential subjugation of the lower groups is implicit in an economic absolutism of price. Beyond any political or social control is control by price. Millions with no voice in any price setting, with no part in contracts but acceptance of dictated terms, pay the price printed on the tag, knowing not the first thing about its fairness. The power exercised by the man who writes a nation's songs is as nothing compared to that of the combine that writes the price tag. In one of the romances of the future by H. G. Wells the lower social strata are represented as living underground, driven off the face of the earth. Such picturesque outcome is less likely to take place than that model tenements will be erected and that low IQ life will be regulated to a maximum of contribution to the upper strata. Cruel neglect and shortsighted indifference to the welfare of the lower levels are as unlikely as would be a recrudescence of dealing with the insane and the criminal after the manner of the Middle Ages. The poor, always to be with us if there is correlation between wallet and wisdom, will be less commonly regarded as blamable or responsible for their condition; and governmental paternalism, instead of being mentioned apologetically, will be regarded as the only logical policy of the state, while a commercial paternalism, of which the pension system of the Northern Pacific Railroad is only one example out of thousands, will round out a total effort grandly dramatizing the idea of a father caring for his children, not to say safeguarding the goose that lays the golden eggs. The lower IQ strata will probably be guaranteed against extinction or extreme degradation of standards of living by a diffused humanitarianism and an application of the principle of intelligent exploitation, tempered with fear of sabotage. It is, of course, quite possible that intellectual aristocracy of the Russian or the Italian type, while effectually disposing of the democratic tradition and striking down the idea of the wisdom of the common man, will nevertheless provide for him as he never has been taken care of before; the care he receives will be that of paternalism, vastly improved but logically heir to the feeding and housing of dusky plantation workers by their mental superiors in slavery days.

The rôle of the least capable citizens will be as heretofore that of assent, ratification, discontent, protestation, resolutions, mass meetings, jubilation, proud suffering and ostensible power, while less and less will actual self-government be realized. Technical management of the affairs of state must of course fall to those who are adept in law, engineering, administration and propaganda, whose work will be reacted to often with no greater aptness than that shown by the Romans who held emperors responsible for the weather. But a rough check on government action may be expected from the 50 per cent. who can scarcely qualify for balanced criticism or constructive suggestion. Through indirect suggestion and propaganda engineering the art of government will progress in the direction of allowing voters of lower mental qualification to believe their will is to be carried out. Nor can any one deny that it does not require the highest IQ to sense rottenness in the state of Denmark. Statesmen of paternalism and the administrators of commercial overlordship will have many a restless night—in fear of what the heathen in his blindness may do, mistakenly of course. The widened suffrage and the absence of educational and mental qualifications for voters give the state a fully representative character, but effectual participation in social con-

trol on the part of the least able must manifestly be slight.

What form the power to rule, derived from superior intelligence, will take, what scenes of paternalism will appear, remain to be seen. A modern version of noblesse oblige may allow a Ford to the IQ of 70, stiffen the blue sky laws against plunder and so carry on that nothing so obnoxious as throwing moronic instalment debtors into prison will occur. But the reflection of mental differences in the institutions of a high-powered age will surely be much unlike the picture of a pleasingly simple democracy. Even with the diffusion not only of knowledge but of knowledge of economics and the state, a sort of learning out of which the poor might build weapons and defenses, the disparity in shrewdness and reasoning leaves the field open to advantages to those who rank highest in native ability.

Paternalism? We can only hope that the lower millions may have great leaders and that the classes who have mental power by birth will conceive of the state in terms inclusive of the welfare of the mass, for the inequality of the brain cells is great.

THE DEVELOPMENT OF A MAGIC FORMULA

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Introduction

If we are to understand the development of such social phenomena as magic and totemism we must change our technique of approach.

For the most part, the method of anthropologists has been that of studying the phenomena as they exist and function in the so-called primitive societies. Using this material as a point of departure they have attempted to unravel the threads and thus learn how the complex developed. Thus far, except for establishing the elements or threads of the phenomena and their relations to each other, we have accomplished but little. As yet the processes of their combination remain obscure.

This is not at all surprising. Any one could take a piece of woven cloth, unravel it, study the materials used in it and tell the manner in which the threads were combined, but this would throw no light on the modern processes by which it was manufactured.

Our position in regard to magic is much the same. We have unraveled it, learned the materials of which it is made and know quite definitely how it goes together, but we do not know the processes by which it is put together.

The only technique by which we can study the processes of the development of magic is that of observing it grow up in contemporary society. We need not seek out primitive groups to find magic. It exists in modern society and, more significant still, is even now in the process of formation.

So far as I know, the only studies using this technique are those of Professor Ralph Linton, "Totemism in the A. E. F.," published in the *American Anthropologist* of June, 1924; and of Professor Kimball Young, "The Story of the Rise of a Social Taboo," published in the Scientific Monthly of May, 1928.

The following account is a picture of the process of the development of a magic formula.

I

One of the perplexing problems which is constantly demanding more and more the attention of the Iowa farmer is the

increasing menace of the Canadian thistle (*Cirsium arvense*).

This weed, which is constantly moving southward and forcing itself upon the attention of the agriculturist as a major problem, is extremely difficult to eradicate, and in the face of the most persistent and resourceful efforts on the part of the farmers, directed by the various agricultural experiment stations, it has not only held the ground already invaded, but even continued its southward migration. An agricultural bulletin describes it thus:

> The jointed, horizontal root stocks are the most obnoxious part of the plant; round, slender, like tough white whip cords lying so deep in the ground as to be always sure of moisture, they creep in every direction for rods, even sending up new plants at intervals; if broken and dragged about by farm implements the pieces grow, so that ordinary cultivation but serves to spread the pest.

The extent to which the farmers recognize the necessity of eradicating it is shown by the methods of combat. It is a common sight to see a large patch of ground completely covered with tar paper in an attempt to destroy the weed by shutting it off from the sunlight. Another method used is to pour gasoline on the plant, saturate the ground around it and then set fire to it. Other farmers may cover the infested land with salt, which not only kills the thistle but sterilizes the ground for a period of years.

Such a problem, of course, occupies a prominent place in the minds and conversation of the farmers living in infested areas. At the noon hour during the threshing season the men often exchange information which they have about the pest, and tell of their friends' as well as their own experience with it. Often they will refuse to allow the machine to thresh for a farmer whose field is infested until all the other men in the "ring" have finished.

Out of this background has come a magical means of eradication, the development of which may be traced in the following narrative.

On or about August 25, 1925,[1] a hot, dry summer day, John M. and his son went out to their field in which was a small patch of ground infested with the Canadian thistle and cut the weeds off close to the ground with sharp hoes.

The next year they were much surprised to find that the thistles did not come up again. Mr. M. and his son talked it over between themselves and with their neighbors, one of whom contributed an old superstition that "everything has a certain day upon which it may be easily killed."[2] At this time it was decided that Mr. M. had discovered the Achilles' heel of the Canadian thistle. It could be simply and easily exterminated if it was cut down on August 25.

Such news was not long in spreading throughout the community and on the next August 25 many farmers went out armed with hoes in their war against the thistle. In some cases the battle was successful and in others it was not. Cases of failure, however, did not invalidate the discovery, but rather strengthened it, "For," contributed some of the old heads, "everything not only has its day but also its hour." They were on the right track and had only to perfect the formula.

By the summer of 1928 the idea had diffused throughout the county, and I have noticed it in the surrounding counties as well.

II

We may let the story rest at this point and analyze the conditions in the society underlying the development of the magic

[1] There seems to be considerable doubt as to the date, as Mr. M. did not realize the importance of the day until the following summer. One neighbor who saw him cutting the weeds claims the day to have been the twenty-seventh. This is a moot point in the community and both days have their followers.

[2] For the possible origin of this superstition in our culture see Eccl. 3: 4.

formula and the steps by which it developed.

1. We have a severe crisis which was felt by the group. The pest must be controlled for the welfare of the group which depended upon agriculture for a livelihood.

2. There is a great difficulty in coping with the situation which had never been defined, and all natural ways were extremely difficult, wasteful and unsuccessful.

3. Following the failure of the scientific methods disseminated through the channels of the agricultural experiment stations many individuals experimented with methods of their own.

4. The element of luck enters, in the form of the combination of several factors, such as temperature and lack of moisture extending over a considerable length of time which prevented the thistles from growing after they had been cut down.

5. The phenomenon is interpreted in the terms of an old and well-established superstition which builds up a false association between the time of an act and the result.[3]

[3] This type of association is common in magic.

6. The rapid diffusion of the trait is probably due to the fact that it was the corollary of a well-established superstition and seemed to meet the situation as well, considering its ease, as did the methods recommended by the experiment stations.

7. Cases of failure, which as with all magic are common, were met by the usual rationalization that the formula had not been followed exactly or that some item was still undiscovered.

III

In mentioning the wider aspects of this incident we should note the importance of the crisis or new undefined situation which is difficult to meet and in which scientific methods were extremely difficult and uncertain. In the second place there is the element of luck or chance which made this simple method appear successful, and in the third place a false association made in terms of an equally erroneous premise.

Were it not for the comparatively high development of a scientific culture it is not unlikely that such a phenomenon would persist and take on all the characteristics of a highly ritualistic magic formula.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

PLUMBING THE DEPTHS OF THE EARTH

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To get to the bottom of things, to find out what makes the machine go, are ambitions worthy not only of the child but of the man. The real essence of the scientific spirit of research is the desire to see the unseen, to discover the secrets that are forever concealed from the casual observer but are frequently revealed to him who is sufficiently persistent in the quest for knowledge. This is just as true of the science of the earth as it is of the science of the stars. Until recently, knowledge of the earth has been largely confined to that which may be directly observed on land and sea. But in recent years it has become increasingly apparent that much which we ought to know is concealed beneath the surface on which we live and move. Some of the most fundamental questions, such as why there are continents and ocean basins, what makes the lofty mountain range stand above the lowly plain, can be answered only when we know the nature of the deeper interior of the earth. Many of our most valuable stores of petroleum and ore are so deep in the rocks of the earth's crust that their presence could never be inferred from what may be seen on the surface. Plumbing the depths of the earth is therefore a task of the greatest practical as well as scientific necessity.

The deepest mine which men have thus far dug is about 7,500 feet deep, only one three-thousandth part of the earth's radius. The deepest well which men have thus far drilled is about 9,000 feet, nearly one and three quarter miles, yet not much of a start on the long journey of four thousand miles from the surface to the center of the earth. As far down as man has gone he finds rocky material quite like that which he sees wherever the solid rocks of the earth's outer shell are exposed to view. The limits of deep drilling have not yet been reached, but at best this method of plumbing the depths of the earth can never do more than slightly scratch the earth's skin. Other methods must be used if we really want to know what is in the earth beneath us, and several are now at hand.

Earthquakes, for example, make their contribution to knowledge. Whenever one occurs, it starts a series of vibrations through the earth which spread in all directions like the ripples on the surface of a placid pool when a pebble is tossed into the water. These vibrations pass completely through as well as entirely around the earth and may be detected by sensitive instruments, called seismographs, designed for this purpose. At present there are nearly two hundred seismograph stations scattered over the surface of the earth at government observatories, universities and institutions for scientific research. Every violent earthquake is recorded on many of these instruments. Several times a year, old mother earth shrugs her shoulders with sufficient violence to shake the entire surface of the globe. Only close to the place at which the movement originates is it of sufficient intensity to cause any damage. At distances of only a few hundred miles it is usually quite imperceptible to human senses, but the vibrat-

ing waves are detected at distances of thousands of miles, in fact clear around the earth, by properly adjusted seismographs. Thus the progress of the waves as they advance through the solid rocks may be observed. Each wave is in fact a messenger which starts, let us say, in Japan and dives deep toward the center of the earth to emerge at St. Louis or Cambridge, Massachusetts, or London or Bombay with the news which it has picked up along the way. Its message is in hieroglyphics, the quivers of a jerky line traced by pen point or tiny beam of light upon the recording paper in the seismograph. Like a secret code, it must be translated before it can be understood.

The velocity at which the earthquake vibrations move through earth material is determined by the elasticity and density of the material encountered and by the nature of the vibration itself. In general, it takes about twenty-five minutes for the swiftest earthquake waves to travel by the most direct route from the point near the surface at which they originate to a point on the surface directly opposite on the other side of the globe. This route is of course through the center of the earth and is therefore about 8,000 miles long. This is about the rate at which such waves travel through glass or steel, and it indicates that the earth as a whole behaves as though it were composed of material as elastic and dense as would be a sphere of glass or highly tempered steel of its dimensions. No great ball of molten rock with a thin crust of frozen surface material could possibly behave as does the earth. The earthquake messages tell us unmistakably that the earth is much more solid than it used to be considered. Its interior may be very hot but it can not be essentially liquid.

But earthquake velocities vary from place to place within the earth. In general, the deeper the path the swifter the movement. This is largely due to the increase in density with depth. Each cubic mile of rock is under pressure equal to the weight of a column of rock one mile square and as high as the distance out to the surface. Such a column a thousand miles high puts tremendous pressure upon the rocks at a depth of a thousand miles. In consequence the rock at that point is compressed so that it transmits vibrations much more rapidly than it would do were it at the surface.

However, whereas pressure must increase rather regularly from surface to center, the travel rate of earthquake waves changes irregularly with depth. In fact, as these waves approach the center and pass through the material at great depths they are quite abruptly slowed down from velocities of eight or nine miles per second to velocities of only five or six miles per second. The only possible explanation of this fact is that the material there must be very different from that nearer the surface. In all probability, the central core of the earth is composed not of rock with high elasticity, but of a metal like iron which is far less elastic. Judging from the composition of meteorites, which presumably are samples of the stuff of which planets are composed, the earth's core is a mass of mixed iron and nickel.

This central core has a radius of about 2,500 miles and thus extends a little more than half way from the center toward the surface of the earth. It can not yet be told with certainty whether the metal of which it is composed is in a solid or a fluid state. Records of earthquake waves that have passed through it are exceedingly difficult to interpret, and much attention is at present being given to this problem.

Surrounding the central metallic core there are several successive shells of rock of somewhat varying composition as indicated by the various rates at

which the vibrations travel in them. These are all known to be quite solid although not necessarily crystalline. In fact it is quite likely that at a depth of only a few miles below the surface the rock is essentially a glass which can be deformed much more easily than such surface rocks as granite or sandstone. This presumably makes possible the movements of the outer crust which cause changes of level of the land along the seashore and give rise to mountains. Such movements are themselves the cause of earthquakes, which in turn provide us with important information concerning the nature of the earth's interior.

The rocks in the surface layer of the earth are notably different from place to place. In general those beneath the sea are heavier and more elastic than those beneath the land. In consequence the earthquake vibrations which travel around the earth through this outermost of its several concentric shells move at different rates. The vibrations of a California earthquake, for example, travel more rapidly toward the west through the floor of the Pacific Ocean than they do to the east through the continent of North America. Even within the continent there are important differences. Limestone generally transmits vibrations at much higher speed than does sandstone or shale.

This fact can be used to advantage in the attempt to discover the nature of rock formations a few hundred or a few thousand feet below the surface. There are many large areas of land throughout which the bed-rock formations are entirely concealed by soil, sand, clay or gravel. Some of these concealed rocks contain oil or other minerals of great value. For example, there is not the slightest suggestion at the surface of the presence of oil in the newly discovered oil field south of Oklahoma City. Yet the oil pool there is undoubtedly one of America's greatest reserves of petroleum. No geologist could have told from surface evidence that that locality was likely to produce oil, because the oil-bearing structure is not revealed in any way. The same is true of several of the important fields of the Texas coastal plain.

But in the last few years several methods of discovering valuable information about these concealed rocks have been perfected sufficiently to make them a great aid in the search for the raw materials upon which our modern industrial prosperity depends. Those methods of plumbing the depths of the earth are known as geophysical prospecting. They involve the determination of physical properties of rocks such as differences in elasticity, in specific gravity, in electrical conductivity and in magnetic attraction.

Take the first of these as an illustration. An explosion of dynamite causes a miniature earthquake. The vibrations from even a comparatively small explosion, say fifty pounds of dynamite, can be detected by properly designed seismographs at distances ranging up to five or ten miles. These vibrations travel at velocities which differ with the different rocks, and therefore the travel-time may be used as an indication of the nature of the rock traversed. If, for example, there is a great mass of rock salt, such as is found in each of the salt-dome oil fields of Texas and Louisiana, between the place at which the charge of dynamite is exploded and the recording seismograph, the vibration will come through in a much shorter time than usual.

Again, the rock salt is very much lighter than the ordinary rocks and so exerts less gravitative attraction. The differences are slight but they are sufficient to be detected by the torsion bal-

ance. This instrument is a very sensitive one, with delicate adjustments, which is designed to reveal slight differences in the force of gravity. Wherever there is a fairly large mass of either unusually light or unusually heavy rock material within a few thousand feet of the earth's surface, the gravitational field is distorted. The torsion balance indicates the amount and direction of this distortion and thus suggests to the observer the location of such rock masses. Salt plugs in the coastal plain of the United States are deficient in specific gravity, and therefore their presence may be revealed by the torsion balance.

Other geophysical instruments are now in use which indicate variations in magnetic attraction which may be due to differences in the amount of certain iron oxides commonly found in many of the sedimentary rocks as well as in some of the igneous and metamorphic rocks. The interpretation of the information gained from the use of the magnetometer, the torsion balance and the seismograph is extremely difficult. In many instances there are several equally rational interpretations which may be placed upon the same body of data. The use of such instruments in the search for oil or other valuable resources can not therefore be considered an exact science. The technique of operation requires great skill, but even greater ability is demanded in the art of interpreting the records obtained. Nevertheless these instruments have already justified the large expenditures of time and money that have been made with them. More than one hundred salt plugs, many of which are accompanied by valuable oil accumulations, have been discovered in Texas and Louisiana within the last five years by geophysical exploration.

To some, this method of plumbing the depths of the earth seems to hark back to the days of the charlatan with a divining rod or so-called "wiggle-stick." The new methods at first glance seem to be quite as mysterious as those of the water witch or oil diviner. As a matter of fact, there is absolutely no comparison to be made between the two. The geophysical instruments operate in precisely the same way regardless of the individual who observes them. They are in no sense dependent upon the psychology or other idiosyncrasies of the operator. Nor is there any representation that the physical apparatus indicates directly the presence or absence of petroleum. Geophysical explorations depend upon perfectly valid scientific principles and give definite information concerning certain characteristics of the rocks in the neighborhood of the stations at which the observations are made. These characteristics are of value as an aid in the interpretation of the underlying rock structure. Where the structure is favorable it is wise to continue the search for oil by means of the drill. Where the structure is unfavorable it is unwise to expend additional sums in drilling operations. In the last analysis, only the drill can reveal with certainty the presence and quantity of petroleum.

The entire science of geophysics, which has as its primary motive the discovery of facts concerning the interior of the earth, is still in merest infancy. A most attractive field for scientific research has at last been made accessible, but only a tiny fraction of the territory has thus far been explored. There is need for much more knowledge in all departments of this new science. In the light of the present situation it may be safely asserted that the next twenty or thirty years will reveal many times as much valuable information concerning the depths of the earth as is now available.

WHAT GERMS ARE MADE OF

By Dr. WM. CHARLES WHITE

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WHAT is a germ? A germ or bacterium is the smallest living thing we know. But in spite of its exceedingly small size it is among the most important of all living things. Some germs are indispensable to us—we could not live without them—while others live at our expense, causing disease and death.

Germs are usually five hundred times too small to be seen by the naked eye. To understand what they are made of one must be familiar with the last few years of the journeys of man's mind into the unknown, and with the evolution of his special mechanical skill. Two great steps furnished our ability to separate individual germs and get them in pure strains. The first was made by Dr. Robert Koch, of Germany, who discovered the tubercle bacillus and founded modern bacteriology, and the second by M. A. Barbour in the United States about twenty-five years ago. Dr. Barbour is now in Lagos, Nigeria, studying yellow fever.

Koch found that germs placed in sterile water and shaken vigorously, when poured on a glass plate covered with sterile solid food stuff like coagulated egg, would start colonies from individual germs. By using a fine wire and touching one of these individual colonies he found that he could transplant one kind of germ on a new clean food supply and that this germ strain would multiply into other germs and that all the germs would be of one kind.

Barbour found that he could pick out from a suspension of germs one single germ. He did this by using fine flint glass tubing drawn out to a microscopic size in a gas flame. When one does this the tube always keeps its hole. Barbour found that this fine tube with its tiny little hole could be made to suck up only one of the germs when brought in contact with it under the microscope and that then this one germ could be planted on new food to grow a colony of its own kind.

As a result of the work of these two men we are able to grow enormous quantities of one kind of germ and chemists and biologists can study what they are made of. You may ask, "What is the use of studying such a thing?" Well, all the life of plants and animals and man is dependent on the work of germs in nature. Some germs are essential to life and others are very dangerous and cause most of the diseases of plants, animals and man.

Those plots of ground in which flowers, vegetables, trees and grass grow luxuriantly may contain one hundred and fifteen million busy germs in a half of a square inch. These germs are of many different strains, each strain doing its own work, such as taking nitrogen from the surrounding air and soil and forming first ammonia, then nitrites, then nitrates, which the plants can use and prepare again into organic nitrogen which can be used by animals and man. Germs set free carbon in the form of carbon dioxide into the air and the plants then take it up through their chlorophyl or green coloring matter which, combined with sunlight, builds up the carbon dioxide into sugars and starches and cellulose for the food of animals and man. Any one who makes home-made wine or beer to-day and watches the busy bubbling and fermenting that takes place can see the results

of germs at work setting free carbon dioxide which passes off into the air for the further use of plants and man.

All living things in their turn become sooner or later food for germs, to be broken up and turned over again into usable form in the grand cycle of carbon and nitrogen and oxygen in nature. All our breadmaking, our tanning, our curing of tobacco, the making of vinegar and sauerkraut, our cheeses, the food of our silos, our wines, are carried on or prepared for us by germ action.

But, as I have said above, germs are not always good to us for they also are the cause of nearly all the diseases of plants, animals, and man. Is it any wonder then that scientists are forever searching for what they are made of and how they work? By being able to understand them he may be able to develop ways of helping the useful germs do their work better and hindering the work of the harmful ones.

We now know many thousands of strains of germs more or less intimately. These are divided into classes, orders, families and species just as other living things are classified and every strain has its own peculiar work to do and its own peculiar way of doing it. You have heard how each species can be obtained in pure form and how each one of the germs in a pure colony is like every other germ. More than this, each germ is just one cell during both infant and adult life and because it is just one cell it offers to the chemist and biologist the simplest and purest form of studying the processes of living nature. It is not like man, made up of myriads of cells!

Until we understand the living chemistry of individual strains of germs and the contrasts between the strains of a family we will still be groping in the dark in our efforts to understand all living processes. It is probable by searching for the chemical differences in strains of one family of germs, the members of which look and act very much alike in the laboratory but which are known by other observations to act very differently in nature, that we may find the reasons for these differences. Already great progress has been made both in industry and in medicine. For example, by finding that different strains of a family of germs will grow on very simple food material, such as in water and a few salts, it is possible to subtract the sum of what was in the food from what is there after the germs grow on it and to find in what is left what the germs have made. It is possible further to take these products of the growth both from the food material and from the germs themselves and find both their chemical nature and what happens when we put them into animals that is their biological nature.

The studies that have been carried on by the National Tuberculosis Association with money raised by the sale of the Christmas Seal will serve as an illustration to show what the different strains of the tubercle bacillus, or the germ which causes tuberculosis, makes. In the acid-fast family of bacteria to which the tubercle bacillus belongs there are some fifty or more known strains. There are three well-known ones of the tubercle bacillus—the strain that causes tuberculosis in cattle, the strain that causes tuberculosis in man and the strain that causes tuberculosis in chickens. To this same family also belong the various strains of germs which cause leprosy. The object of the studies which the National Tuberculosis Association has been carrying on is to find what these germs are made of, how they do their damage and kill, and, if possible, how to interfere with their evil processes so that benefit may come to all those who are sick with tuberculosis.

You will want to ask, How can a germ made of one cell only contain enough power in its minute body to

make a million like it in a day, each having the same quantity of all the substances that the first cell possesses? For like the widow's cruse of oil, it is a never-ending power, or the spark of life, always elusive. There are, however, some fractions of this life element that can be separated for further study. For example, each living germ has in it certain substances called ferments or enzymes. To most of you and in fact to everyone these names are only names, words used to tag a substance which we little understand. But we can make solutions of them. You are familiar with essence of pepsin, which is a ferment, and you see the work of an enzyme when yeast makes bread rise and when wines begin to boil. Likewise we can make solutions of the ferments of germ strains and compare their work. But we can do this only if we grow one strain of germ in sufficient quantity to provide us with enough material for study.

Each germ strain has its own peculiar enzymes and we know little enough about them, but when a single germ is put into a quantity of simple food solution it is its enzymes which start to work. These begin by creating currents similar to electric currents between the germ cell and its surrounding water and salts, back and forth, until inside the cell a change in internal chemical arrangement occurs and then suddenly two cells are made. Then from two cells come four, and eight, in regular progression until we have a vast number.

A second group of substances are the pigments. These also, like the ferments, are little understood but are peculiar to each germ cell. The pigments take their energy from the sun as electric currents just as the chlorophyl or green color of plants acts for the plants.

With these two tiny machineries operating all the while, the germs manufacture sugars of rare type, starches, albumins, fats, and a great variety of substances known as toxins and ptomaines. These complex substances of which the germ body is made and which are often peculiar also to the strain of germ cell can also be separated as solutions, purified and studied for their chemical structure and biological action. For instance, there are two very closely associated germ cousins that cause pneumonia in man, but although they both produce pneumonia they make entirely different sugars which can be separated in pure form. They are different both chemically and biologically and are very hard to break up except by boiling in acids. Recently however Dr. Oswald T. Avery, of the Rockefeller Institute, found a ferment enzyme in one of the germs of the soil of the blueberry bogs which will break up these sugars into glucose and carbon dioxide. The action of such a ferment is nature's way silently and efficiently of breaking up dangerous poisonous substances into simple useful parts which can be used by plants and animals to carry on their life processes. How different is the silent way of nature from the crude, often noisy way of man, in the laboratory. To do the same thing that the blueberry bog germ does man must boil with a strong acid. It is certain that we do not destroy poisons in our bodies by boiling with sulphuric acid.

Among the toxins and ptomaines that germs make, you know of the poisons of diphtheria, scarlet fever, smallpox, food poisoning. Each disease-producing germ manufactures its own toxin, some strains in a family more than others. These poisons cause fever, sickness and death even when they are separated in solutions from the dead or living germs.

Germs produce also fats and waxes. For instance, the tubercle bacillus

family produces a wax nearly like beeswax but in addition it produces several fats of very rare character.

When we consider all these substances that germs are made of, it would seem that the hope of the future lies in a study of the comparative chemistry of the different strains of each family in a systematic methodical way so that we will know in what chemical units are the causes for the differences between the germs of disease, and the germs that help us. When we understand where each family and each member of each family differs we can very probably strike at those differences in such a way as to make them either more active, if the germ is a useful and helpful germ, or make them harmless if the germ is dangerous.

SOME POPULAR MISCONCEPTIONS ABOUT THE AMERICAN INDIAN

By M. W. STIRLING

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WHEN I was a small boy, the Thanksgiving season always brought to mind rather confused pictures of the Pilgrim fathers alternately fighting off savage attacks of the Indians and receiving from them gifts of corn, pumpkins and turkeys. The general impression which I retained was that, while the Indians had occasional altruistic outbursts, on the whole they were savage and undesirable neighbors.

In the Peabody Museum at Harvard University is preserved what is probably the oldest relic in the United States procured by white men from a living Indian tribe. This is an Indian bow dating back to the early New England colonial period. An ancient label still adhering to the specimen reads as follows: "Indian bow, taken from an Indian at Sudbury by John Goodenough, who shot the Indian." A long and interesting tale of misunderstanding precedes the penning of this terse statement.

In the year 1608, Edward Harlow was sent in a ship by Captain John Smith of the new Jamestown colony to explore the Cape Cod region. When he landed there and the Indians came out to meet him, he seized five of them and carried them off, taking them with him to England. The next touch of hospitality encountered by the Indians of the Plymouth region was when Thomas Hunt was sent there from Jamestown in 1614 to determine the desirability of the site for colonization. When he landed the Indians came to meet him in a friendly manner. He invited them on his ship and as soon as they were aboard clapped them all, twenty-four in number, under hatches and carried them off to sell them as slaves to the Spaniards. One of the Indians who later escaped was brought back to Plymouth by Captain Dermer who attempted to regain the good will of the Indians of the region in 1619. However, the natives, in view of what had happened on the two previous visits, were not in a mood to parley.

The next year, 1620, was the year of the landing of the *Mayflower* and the Pilgrim fathers. It is not surprising that they had difficulty in making contact with the Indians. The first shore party that landed found several houses from which the Indians had fled. Near these were large pits filled with corn which the Indians had stored for their winter supply. The colonists promptly robbed the pits of all the corn which they contained and the houses of their

utensils, all of which they brought with them to the ship. Several days were spent by the colonists in cleaning out the corn caches of the neighborhood and in addition several graves were dug up and the articles accompanying the burials taken. Had it not been for Squanto, the English-speaking Indian who had been returned the previous year by Captain Dermer, the colonists would probably never have encountered the Indians on a friendly basis. Furthermore, without the instructions of the Indians in regard to planting, the colony would have failed from starvation the first year of its inception, and there would have been no Thanksgiving to celebrate.

The experience of the Massachusetts Indians was typical of the sort of greeting the Indians had received from the time of the first landing of Columbus. The fact that in many places they had the spirit to defend themselves against robbery and slavery gave rise to the first of our list of conceptions "that a good Indian is a dead Indian."

Despite his reputation to the contrary, the Indian was not by nature particularly warlike. Tribes that in later days bitterly obstructed the invasion of the whites, were invariably, on first contact, friendly and hospitable.

Some of the tribes of the Great Plains practiced a peculiar sort of warfare as a manner of gaining individual prestige, and the Aztecs seemed to be on the verge of developing an idea unique among Indians: that of supporting themselves by conquest. Most Indians, however, avoided fighting whenever possible, but fought fanatically when driven to it.

Warfare among the Indians was not as a rule a tribal matter excepting in the case of defensive fighting for mutual protection. War parties were organized by individuals, usually adventurous young men. Any one might organize such a party and collect such volunteers as would accompany him. Frequently wiser old men would attempt to dissuade such an exploit but no one had authority to prohibit such a venture. Actual fighting was as a rule by ambuscade or surprise attack. Military tactics were never used until the benefits of organized fighting were learned from the whites.

The earliest of all the misconceptions about the Indians arose immediately upon the discovery of America, when Columbus thought he had reached the East Indies and therefore called the natives "Indians."

Early in the 16th century, when America became definitely recognized as a separate continent, Europe began to speculate upon the probable origin of the natives. By this date Christianity had become firmly entrenched as the religion of Europe. In keeping with the religious spirit of the age, a solution of the problem was first sought in Hebrew tradition. As a result there were soon circulated many publications purporting to demonstrate that the Indians were descendants of the "Lost Tribes of Israel." As there are certain basic similarities in the customs of primitive peoples throughout the world, it was an easy matter to demonstrate resemblances between the American Indians and the early Hebrews.

Speculation did not stop at this point, however. Energetic writers began to see resemblances between the pyramids and temples of Central America and Mexico and those of ancient Egypt or India. Others thought that they could see the hands of the Phoenicians or the Greeks in some of the customs of the Indians; in fact, most of the high civilizations of Europe, Asia and Africa were each supposed by some writer at some time to have been the point of origin of the Indian or of his civilization. Not content with having exhausted all of the known culture centers of antiquity, enterprising theorists had

drawn upon mythical or assumed civilizations in order to furnish parents for our orphan natives. The myth of Atlantis and the theory of a lost continent in the Pacific have furnished colorful material for fanciful accounts of forgotten migrations.

The story of tribes of "White Indians" is one of the most persistent of the legends connected with the alleged exotic origin of the Indians. As early as the seventeenth century Wefer noted the frequent existence of albinos among the natives of Panama, and there have been frequently occurring notices of these people since that time. The supposed ancestors of these groups have been variously attributed to the Norsemen, the Irish, and the Welsh.

In connection with popular ideas of this nature there might be mentioned the widespread belief in the past or present existence of such abnormalities as races of giants, pygmies or people with tails. The folk lore of the Indians contains many tales of giants and dwarfs to which credence has been given by white hearers in many instances. In old burials unskilled observers have frequently mistaken the skeletons of children for those of dwarfs. The fallacious idea of a race of dwarfs is probably most prevalent in the Pueblo region of the Southwest. This is due partially to the finding of the mummies of children, and partly to the frequent occurrence of miniature storage rooms with small doorways, these having been interpreted as the dwelling places of pygmies.

Never a year passes without at least one newspaper report of the finding of the bones of an alleged giant. These finds when investigated invariably turn out to be the bones of large mammals, fossil or otherwise, supposed by the discoverers to be human remains. In some instances actual human remains in a burial have become separated in such a manner as to give to the untrained observer the impression of abnormal stature.

It might be said at this point that the studies of anthropologists have demonstrated that the American Indians are essentially of one racial type, probably the basic type from which the Mongoloid peoples of Asia have also sprung.

There are a number of beliefs which have long held general credence concerning the existence of pre-Indian or non-Indian races in America. It was believed for a long time that the mound builders of the Ohio and Mississippi valleys and the cliff dwellers of the southwestern United States were not only racially distinct from the Indians, but possessed a civilization superior to them. These beliefs have persisted in spite of the fact that it is now well known that many of the mounds were erected during historic times, and their function described by early travelers. Many of the mounds when excavated contain numerous articles of European manufacture. The skeletons and artifacts found in the pre-Columbian mounds show that their builders were Indians with a culture differing in no material degree from their historic descendants.

The pueblo dwellings erected on the cliffs in the arid Southwest were in no way distinct from other pueblo dwellings either as to the nature and degree of civilization of their occupants or as to the period of occupancy. The cliff dwellings were inhabited simultaneously with the other southwestern villages throughout virtually the entire period of occupancy of this region, historic and prehistoric. We now know from the growth of tree rings in wooden beams found in the structures the exact years in which they were erected. Most of the principal cliff dwellings were edected in the years 1100 to 1300 A. D.

Probably no misunderstanding brought about as much ill feeling and

bloodshed between the Indians and whites as the difference in concept concerning the ownership of land. The land within the tribal boundaries belonged to the tribe as such. Neither the individual nor the family possessed vested rights in land although each family might appropriate for purposes of cultivation as much as they required of any unoccupied land within the tribal boundaries. It was therefore impossible for any chief, family, or any section of a tribe legally to sell or give away any part of the tribal holdings. Naturally any documents or purchases of this nature had no meaning to the Indians. The early settlers seemed never to have learned this fact. Regardless of any negotiations carried on by individuals, the Indians of course considered themselves ousted when the whites took possession of their lands.

The religious ideas of the Indian have been little understood by the layman. Such terms as the "Great Spirit" and the "Happy Hunting Ground" are inventions of the white man. The concept of a ruling, all-powerful deity is a political analogy applied to supernatural powers, which could be conceived only by a people aware of centralized power, such as existed only in the Old World. Far removed from this conception was the Indian belief in a multitude of spirits whose abode was to be found in both animate and inanimate objects. His rituals and sacrifices were conducted with the sole purpose of propitiating these spirits. The Indian in no way mixed his ethics with his religion. Moral principles of good or evil were not a characteristic of his deities, as his religion was purely practical. Consequently ideas of reward or punishment after death or any such spirit abodes as a happy hunting ground or an Indian hell were equally foreign to his conceptions.

The Indian was far behind his European successors in such matters as the control of natural forces and principles, although his observation and knowledge of the organic life of his environment was surprisingly full and accurate. Virtually every Indian was a born zoologist and botanist and a keen observer of nature. The depth and beauty of his philosophy and religion has been but little understood by the white man. As an artist, poet, orator and dramatist he has never been excelled.

It is unfortunate that a general knowledge of these facts comes at a time when in most regions of America the Indian himself has almost forgotten the old customs and the old beliefs. It is a curious fact that the generations to come will have a clearer perspective and understanding of the Indian than did most of his white contemporaries.

A DWELLER IN THE PINEY WOODS

By Dr. FRANCIS HARPER
SWARTHMORE, PENNSYLVANIA

For uncounted ages the piney woods on Billy's Island had stood in their matchless glory. Successive patriarchs of the forest had reared their topmost green sprays ninety or perhaps even a hundred feet toward the blue Okefinokee skies, while the seasonal breezes had played upon their needles, sending down soft Aeolian music to charm each passing generation of men, whether red or white. Here had roamed the Seminole bowmen, including Chief Billy Bowlegs himself, when deer had been as numerous as the cattle of later days. Here the Confederate deserter had made himself a snug retreat during troublous war-times. Here Maurice and Will Henry Thompson had come in 1866 on their earliest excursion to the region, finding a rich field for their literary gifts. At about the same period James Lee, great-grandfather of the present inhabitants, had settled here as a pioneer, winning a livelihood from the wilderness about him. Besides being historic ground, this had seemed, at my first rapturous sight of it in 1912, one of the loveliest of earthly spots.

Nine years later the great brown trunks of the pines, both longleaf and slash, bore the fresh scars of the turpentiners—those melancholy forerunners of the axmen and sawyers. Even so there were delights in store for one roaming through the gladelike woods on this morning of May 16, which had been cloudy and lowery since dawn. For a day and a night previously there had been rain in the great swamp. All the low undergrowth was still wet; saw-palmetto, huckleberry and gallberry spattered me with rain-drops as I brushed through their thick ranks. In almost any direction my view extended for a quarter of a mile through the level, open woods. The vegetation was at its fairest and greenest, and summer bird life was near its fullest tide, for in the Okefinokee mid-May is more summer than spring. The chant of the pine-woods sparrow was fitting music in this outdoor cathedral; the bob-white called its name; the brown-headed nuthatches chattered to each other in the tree-tops; the trill of the pine warbler sounded almost as soft and mellow as the murmuring of the trees in which it makes its home; and now and again other regular inhabitants of the piney woods, such as the joree, the yellow-throated warbler and the wood pewee, contributed their notes to the general chorus.

Presently I became aware of a distinct addition to these songs and calls among the pines—some shrill piping whistles sounding from here, there and yonder. Did this elfin sort of music originate from bird or amphibian? Where were the authors—on the ground, among the bushes or in the trees? How far away were they? For long I could make no headway in solving these questions. Whenever I endeavored to follow one of the sounds to its source, it would cease or retreat, only to be heard from other points. The thing was utterly baffling. I was becoming fairly desperate. But eventually I hit upon an expedient that often works in such contingencies. Carefully getting a bearing on one of the sounds from a certain direction, I moved off at an angle for some distance, then got a bearing from another direction. It now merely remained to proceed toward the point of intersection of these imaginary lines, which luckily fell

FIG. 1. A HABITAT OF THE OAK TOAD AMONG SLASH PINES AND SAW-PALMETTOS ON BUGABOO ISLAND, OKEFINOKEE SWAMP, GEORGIA, JUNE 5, 1929.

in a fairly open space. At the last I got down on hands and knees, and cautiously advancing in this manner, had scarcely covered a yard when a little blackish toad, with a pale golden streak down its back, made a slight movement among the grass and saw-palmettos before me.

Bufo quercicus, the oak toad! Here was a prize indeed. No longer nor wider than the last joint of my forefinger, it is by all odds the smallest *Bufo* of North America, if not of the entire world. It scarcely attains one tenth the bulk of its big cousins, the American toad and the Southern toad. From the babies of these species it may be readily told by its vertebral streak, its relatively smaller head and the bright orange dots about its legs.

While the little fellow before me remained placid and silent, others not far off continued at intervals their plaintive, high-pitched peepings: *pheep-pheep, pheep-pheep, pheep-pheep-pheep, pheep-pheep-pheep-pheep*. After several minutes of motionlessness on the part of both of us, my new acquaintance made a few leisurely forward movements, crawling with one leg at a time, lizardlike, with body off the ground. It was not until I poked a straw at it that it made hops of a couple of inches or so. Eventually it made a few such hops of its own volition, though still crawling for the most part. It was interested in ants running about near it, turning its body to watch them and presently thrusting out its tongue to lick one up. For half an hour I watched it moving freely about within a few feet, but it did not venture to perform vocally, though the heavy showers that fell upon us should have stimulated it. To witness that performance was a treat reserved for later occasions.

The oak toad was originally described in 1840, from Carolina specimens, by the learned Dr. Holbrook in his classical work on "North American Herpetology." It ranges from North Carolina to Florida, Alabama and Louisiana, and seems to be restricted to the Coastal Plain. A lover of dry places, it is found within the Okefinokee only on the islands, such as Billy's, Honey, Jones, Chesser's and Bugaboo. In the sur-

FIG. 2. THE OAK TOAD IS CONSPICUOUS WHEN PLACED ON A PALMETTO LEAF. CAMP CORNELIA, CHARLTON COUNTY, GEORGIA, MAY 24, 1929.

FIG. 3. THE OAK TOAD'S PROTECTIVE COLORATION

MATCHES THE GROUND LITTER IN THE PINEY WOODS. CAMP CORNELIA, CHARLTON COUNTY, GEORGIA, MAY 24, 1929.

rounding region it ranges widely, being particularly abundant on Trail Ridge, between the swamp and the St. Mary's River. Since the driest areas are generally covered with pine barrens (including the so-called "oak ridges"), the toad is a very characteristic species of this habitat, living among the saw-palmettos, gallberries, huckleberries, oak runners, wire-grass and other vegetation making up the undergrowth.

The oak toad gives an impression of being particularly numerous at no great distance from the habitations of man. Is this perhaps correlated with the fact that man tends to exterminate snakes, which must be among the principal enemies of the species? Or is it a simple expression of the desire of both men and toads to occupy the driest available areas in this low country? In this connection I recall several days of heavy rainfall on uninhabited Black Jack Island in July, and several days of variable June weather on Bugaboo Island, where the only habitation was a small turpentine camp, just established. I recorded no oak toads on Black Jack and only a few solitary calls on Bugaboo, though June and July are in the midst of the vocal season. Snakes of various kinds appeared unusually common on the latter island, perhaps because of infrequency of both fires and men. On the other hand, it may be noted that both these islands appear somewhat lower and damper than other islands of the swamp where the toads are more numerous. So the absence or comparative scarcity of oak toads in wet and intermediate pine barrens very likely indicates a strong preference for the driest parts of the piney woods.

Although the larger toads of the East (American, Southern and Fowler's) are mostly crepuscular or nocturnal in habits, the oak toad is frequently found abroad and heard calling during the brightest hours of the day. Probably its tiny size enables it to escape many hazards that might befall the larger toads if they braved the daylight to as great an extent as it does. Furthermore, its variegated color pattern is highly protective in its normal surroundings (Fig. 3). When alarmed, it is apt to cower down, with head held close to the ground, so as to render itself still more inconspicuous than usual.

Rarely have I been able to note in what sort of a retreat it elects to spend its inactive hours. Once, on lifting a slab of wood lying on the ground in dry pine barrens, I found an oak toad occupying a little hole beneath it, about an inch and a quarter in depth and five eighths of an inch in diameter. At another time, while I was trying to maneuver one into position for a photograph, it suddenly backed down into a three-quarter-inch hole in the ground, where it remained peering out of the entrance. Probably the use of such holes for hiding-places is a general habit with the oak toad, as it is with its congener, the Southern toad.

As a vocalist, this is one of the most remarkable of the twenty species of tail-

less amphibians known in the Okefinokee region. Few can rival it in relative expansion of the vocal sac, and none can compare with it in oddity of shape of this apparatus. In spite of the toad's pygmy size, its shrill notes carry to a distance of probably a quarter of a mile.

Its vocal season extends at least from early May to the latter part of August. Heavy rainfall, combined with a temperature above 70° F., produces the right conditions for a tremendous outburst of peepings, either by day or by night. The toads then resort in great numbers to the cypress ponds, or to such temporary waters as roadside pools, puddles in cornfields or flooded grassland. The eager males take up their positions close to the water's edge, in grass, on sticks, pine-cones or clods of earth lying in the water or on floating chips. In moving to some new position, they may take bodily to the water, swimming actively along beneath the surface and pausing now and then to sprawl out with part of the head above the surface. While swimming, they hold the arms curved forward along the sides of the head, the fingers about reaching the snout. Meanwhile the hind legs furnish the motive power. The position of calling is generally out of the water, though at its very edge.

FIG. 4. OAK TOAD CALLING, WITH INFLATED VOCAL SAC.

In a roadside ditch near Spanish Creek, Charlton County, Georgia. Flashlight photographs about 1 A. M. and 1:20 A. M., June 22, 1929.

The vocal sac, when fully expanded at the moment of peeping, takes on the approximate shape of an inverted sausage balloon, almost half the size of the toad's whole body (Fig. 4). It is somewhat compressed, with a greater vertical than lateral diameter. The part of the sac nearest the body has a milky white appearance, but the outer half is translucent and water-colored. In the slight pauses between some of the peeps the sac is deflated to about one half or one third the full size, but sometimes two peeps are given in such rapid succession that no time is allowed for the sac to become deflated to that extent. In the intervals between the series of peepings it collapses almost entirely. The sac is filled with air forced from the lungs, and apparently some of the same air is reinhaled into the lungs. Meanwhile the toad doubtless makes use of a valve, as the frogs do, for preventing the escape of air through the nostrils. The sides of the body are seen to be compressed as the sac swells out to its full size, and they expand again rhythmically as the sac is partly deflated between peeps. The distention of the body during the calling periods is so great that sometimes the toad seems able to touch the ground with only the tips of its fingers; or it

may have to leave one arm entirely suspended in the air (Fig. 4). The comical inflation of the tiny toad, combined with its earnest demeanor, makes a spectacle to be long remembered.

In 34 calling periods of several different individuals in June, the number of peeps ranged from 8 to 37, with an average of about 23. When the toad is in lusty voice, the intervals between calling periods last for only two or three seconds. The rate of calling varies from about $1\frac{1}{3}$ to 2 peeps per second. The slower rate has been noted after the toads had been calling for hours and were perhaps becoming exhausted. The individual peeps are not given at uniform intervals. There is usually an appreciable pause between every few peeps, but marked variation renders it impossible to record a typical series of notes. The following will serve as random examples: *pheep-pheep, pheep-pheep, pheep-pheep, pheep-pheep, pheep;* and *pheep-pheep, pheep-pheep-pheep, pheep-pheep-pheep, pheep-pheep-pheep, pheep-pheep-pheep, pheep-pheep-pheep, pheep-pheep-pheep, pheep-pheep-pheep, pheep-pheep-pheep.*[1] These calls of the males serve a biological function in attracting the females to the bodies of water where mating is to take place.

Fair-weather calls, whether diurnal or nocturnal, are generally rather desultory. But when multitudes of the oak toads forgather during or after especially copious summer showers, the din produced by the elfin bagpipers is simply ear-splitting. Several such gatherings stand out in my memory. Two occurred in the late afternoon in rain-filled depressions in pine lands—one on Honey Island on July 3 and one near Hilliard, Florida, on August 16. Others were at night—at a cypress pond on Chesser's Island, July 16, and in a flooded field near Trader's Hill, July 3. On this last occasion, particularly, our eardrums were in a fair way to cave in; we had to shout to each other to make ourselves understood, and some of us felt the effects in our ears for several hours afterwards. In such a species, size is certainly no safe index of vocal power. During these extraordinary outbursts of vocal activity, when the mating madness is upon them, the oak toads are quite indifferent, even by day, to a person standing within a yard.

During the mating season, which apparently extends from May to August, each female probably deposits eggs at several different periods. A little past midnight on June 22, after a hard storm of the previous afternoon, I observed the act of oviposition in a roadside ditch near Spanish Creek west of Folkston. The male maintained an axillary hold with its right hand, and a supra-axillary hold with the left. The pair paddled along a few inches at a time with the use of their six free limbs. As they came to a definite pause every minute or so, some eggs were expelled and fertilized. While they proceeded toward the next stop, a curious little straight string or two of five or six eggs each could be seen dangling from the female, soon to become detached on a grass blade or other object in the water. In several observed instances, the string of eggs did not fall to the bottom of the shallow pool. Within another day or so this pool had more or less completely dried up, and so the laying had gone for naught. Since many of the waters in which the oak toad breeds are of a very temporary nature, the mortality among the eggs and larvae must be very high.

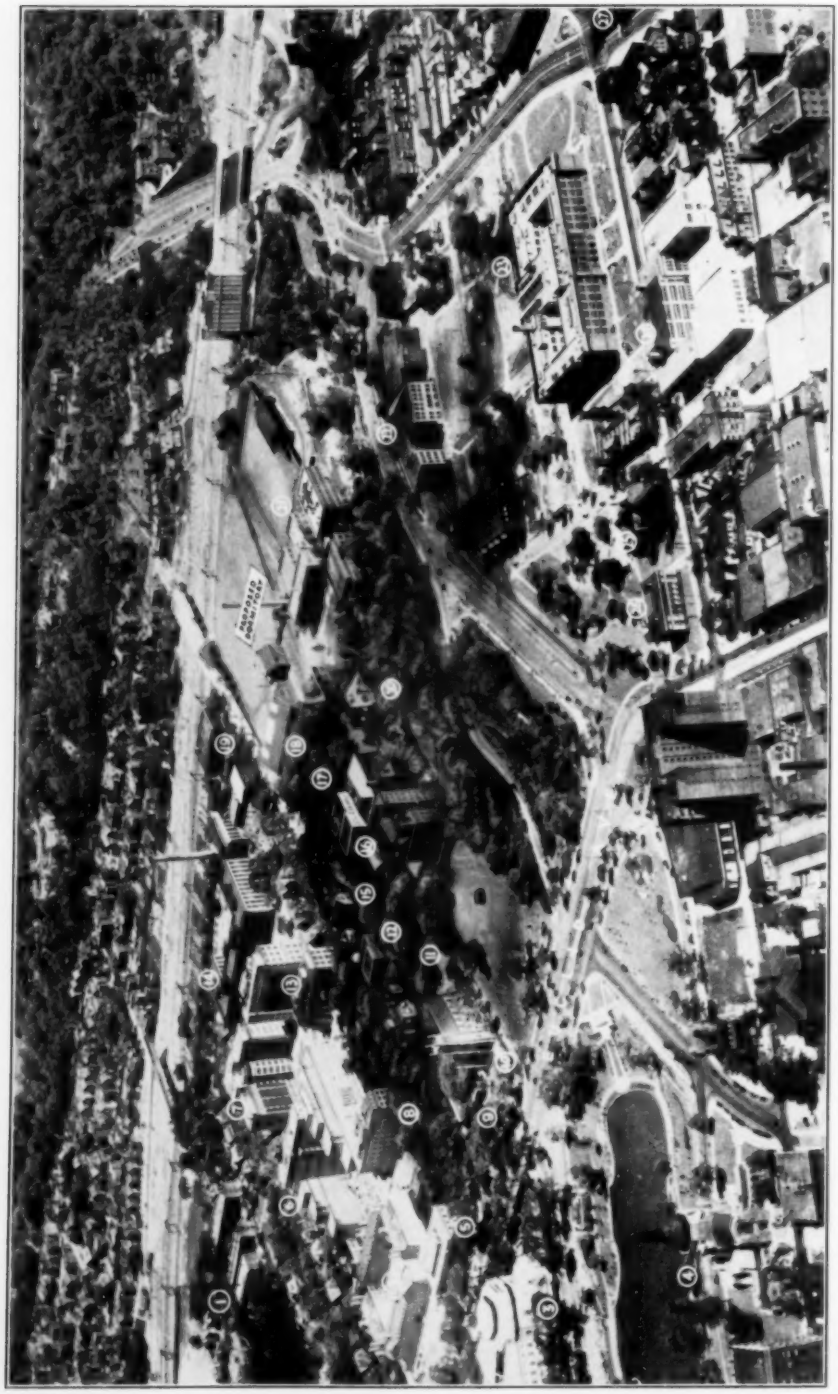
In common with some of the tree-frogs, the oak toad seems to pale out somewhat at night, its color pattern becoming lighter and more distinctly variegated. Its somber diurnal appearance in Figs.

[1] The notes joined by hyphens are given in rapid succession, while the commas indicate pauses.

2 and 3 may be contrasted with its bright nocturnal pattern in Fig. 4. Or is the latter possibly a nuptial rather than a nocturnal coloration?

In various respects—such as the sound of its notes, the shape of its vocal sac and the pulsating manner of inflating it, its diurnal activity, the nature of its eggs and its dwarf size—*Bufo quercicus* seems to be a rather aberrant member of its genus. All the other species of the eastern United States (and some of other regions as well) have a rounded vocal sac and keep it fully inflated during the single comparatively lengthy call, which consists of a generally steady trill, squawk or roar, as the case may be. Two Western species, *Bufo cognatus* and *Bufo compactilis*, by the possession of a vocal sac shaped much like that of *Bufo quercicus*, may show closer relationships with it, but comparatively little is on record as yet in regard to their habits and life histories.

I have had abundant occasion to esteem the remarkably keen knowledge that the Okefinokee residents possess of their wild animal neighbors. It is of particular interest, therefore, to realize how generally they have gone astray in the exceptional case of this tiny amphibian. While its shrill piping sounds through the piney woods, ask any inhabitant of the swamp or its environs to give heed to the notes and tell you what they are. Is it an Okefinokee penchant for accuracy in distinguishing between first-hand and second-hand information that leads him to respond in a manner less direct than usual, "Well, sir, folks *say* that's a black snake hollerin'"? Ten years ago practically every answer, if informative at all, would have been of this sort. Nowadays some will respond at once, with perhaps a not wholly concealed air of satisfaction over recently acquired knowledge, "That's a oak toad." I have become so used to the first type of answer that I confess I am sometimes rather startled by the second.



VIEW FROM THE AIR OF WESTERN RESERVE UNIVERSITY, THE CASE SCHOOL OF APPLIED SCIENCE AND SURROUNDINGS

(18) MARKS THE REGISTRATION HEADQUARTERS AND THE SCIENCE EXHIBIT. (11), (12), (15), (16) AND (17) MARK THE BUILDINGS OF WESTERN RESERVE UNIVERSITY IN WHICH MANY OF THE SESSIONS WERE HELD, OTHERS HAVING BEEN HELD IN THE MEDICAL SCHOOL (14). THE ADJACENT BUILDINGS ARE HOSPITALS. (30) MARKS THE GROUPING OF THE CASE SCHOOL OF APPLIED SCIENCE. (25) IS THE JOHN HAY HIGH SCHOOL, IN WHICH PUBLIC LECTURES WERE GIVEN.

THE PROGRESS OF SCIENCE

THE CLEVELAND MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AND ASSOCIATED SOCIETIES

THE Cleveland meeting was noteworthy in showing very clearly an awakening sense of broad social responsibility on the part of the association's membership. During the past few years there has been evident among those contributing to the programs an increasing tendency to broaden the approach to their subjects in such a way as to make their contributions of interest to a much larger circle. This change of attitude is evidence of the increasing self-confidence of American science, for it is always the timid worker who expounds his subject in such a highly refined and technical terminology that none but specialists in his own line are able to understand what he is talking about.

Of course a highly technical phraseology is and always will be necessary in discussing topics in all the more specialized subdivisions in all branches of science. Yet it is at the same time true that the deeper one goes into any subject, no matter how restricted the subject may be, the easier it becomes to express one's ideas in more or less simple language.

As a result of the increasing proportion of papers which, though incorporated in the technical program, are quite intelligible to any one with a good education, the gap between the so-called popular lectures and the more general papers on the section and society programs is rapidly being bridged. Indeed, at the Cleveland meeting a wholly satisfactory series of popular lectures could have been arranged by simply choosing contributions here and there from the section programs.

An unusual number of papers of outstanding importance were presented at this meeting. These papers included the first public mention of new developments or discoveries of great interest in several different lines. In other papers there was given further information on discoveries which had first been announced within the past twelve months.

There were about four hundred and fifty more papers and addresses presented at the Cleveland meeting than were presented at Des Moines a year ago. Considerably more than half of this increase was in the field of biology and agriculture, together with anthropology.

This increase in the relative importance of the biological and allied sciences at the Cleveland meeting is partly to be explained by the fact that, in contrast to those lines of science more closely related to what is commonly termed industry, the twenty-two societies among which at the association meetings the biological and allied sciences were distributed still find in these meetings the best opportunity for their annual assemblies.

The economic as well as the other aspects of biology is still largely centered in our universities, colleges and allied and similar institutions, so that in biology there is not the dual allegiance —to academic activities on the one hand and to industrial life on the other—that has in recent years become so marked in other lines of science.

But the relative increase in the importance of the biological contributions can not be wholly attributed to its largely academic aspect. It is at least partly due to a relative increase in the general interest in biology itself.

A striking feature of the meeting was the large number of young men and women who attended the sessions and presented papers. This was of course partly due to the accessibility of Cleveland in reference to the scientific centers

MEMBERS OF THE EXECUTIVE COMMITTEE OF THE AMERICAN ASSOCIATION

SITTING FROM LEFT TO RIGHT: DR. ROBERT A. MILLIKAN, RETIRING PRESIDENT OF THE ASSOCIATION; DR. THOMAS HUNT MORGAN, PRESIDENT; DR. J. MCKEEN CATTELL, CHAIRMAN OF THE EXECUTIVE COMMITTEE. STANDING: DR. BURTON E. LIVINGSTON, DIRECTOR OF THE LABORATORY OF PLANT PHYSIOLOGY AT THE JOHNS HOPKINS UNIVERSITY, PERMANENT SECRETARY, NOW ELECTED GENERAL SECRETARY; DR. HENRY B. WARD, HEAD OF THE DEPARTMENT OF ZOOLOGY AT THE UNIVERSITY OF ILLINOIS; DR. DAVID R. CURTISS, PROFESSOR OF MATHEMATICS AT NORTHWESTERN UNIVERSITY. MEMBERS OF THE EXECUTIVE COMMITTEE NOT SHOWN ON THE PHOTOGRAPH ARE: DR. FRANK R. LILLIE, CHAIRMAN OF THE DEPARTMENT OF ZOOLOGY AND EMBRYOLOGY AT THE UNIVERSITY OF CHICAGO, GENERAL SECRETARY; DR. KARL T. COMPTON, PRESIDENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY; DR. JOEL H. HILDEBRAND, PROFESSOR OF CHEMISTRY AT THE UNIVERSITY OF CALIFORNIA, AND DR. VERNON KELLOGG, PERMANENT SECRETARY OF THE NATIONAL RESEARCH COUNCIL.

in the northeastern section of the United States and southern Canada.

For its healthy development science depends on young people with ideas and with courage to expound them. It is gratifying, therefore, to find that a large proportion of the papers on the program were given by contributors whose names are not as yet to be found in the pages of "American Men of Science."

The annual meetings of the association serve three purposes: They provide an opportunity for the exchange of ideas among research workers in the same or similar lines of science; they afford an opportunity for bringing science to the general mass of the population upon whose appreciative support scientific advance is ultimately dependent through the medium of a sympathetic press; and they serve as a forum for those just embarking upon a scientific career.

It may be truthfully said that at the Cleveland meeting the last two aims were more successfully served than has ever been the case before, while the first in no way suffered by the emphasis on the other two.

Besides the interchange and diffusion of scientific thought and of the scientific spirit through the presentation of technical papers and of addresses, and also through social assemblies, the association's meetings are now featured by exhibits of various kinds, both commercial and non-commercial. At Cleveland there was noticeable a marked interest in these exhibits over and above the more or less casual notice which they have attracted at previous meetings.

It is not possible to say for certain whether the increase in the number of people constantly in the exhibit hall was due to the attraction of the exhibits themselves, or whether it was due merely to the fact that the exhibits were more centrally located in regard to the meeting places than has heretofore been the case.

The success of a meeting is by no means a matter concerning the membership of the association alone. It depends very largely upon the spirit in which the association is received by the population of the city wherein the meeting is held.

The association owes the City of Cleveland, the Western Reserve University and the Case School of Applied Science a lasting debt of gratitude not only for the cordial reception of its members during the meeting, but also for the most excellent, thorough and comprehensive manner in which the laborious and intricate work of preparing for the meeting was handled.

AUSTIN H. CLARK

THE SCIENCE EXHIBITION

THE American Association for the Advancement of Science, at the recent meeting in Cleveland, made a new gesture in keeping with its underlying policy of making the advancement in science intriguing and understandable to the general public. This new move was the installation of enticing exhibits illustrative in one way or another of the advances of science through research. It is not feasible nor even desirable to recreate the research worker's laboratory, but rather to set out one or more illustrations from the laboratory which would have meaning and interest to the lay public, as well as to the scientist not versed in that particular field of endeavor.

It is assumed that the botanist stands on about the same footing as the high-school student when evaluating an exhibit in the physical sciences. Moreover, the physicist is generally fascinated by a clever, objective presentation

THE EXHIBIT OF THE AMERICAN MUSEUM OF NATURAL HISTORY

A PHOTOGRAPH OF THE EXHIBIT SHOWING THE WORK OF PROFESSOR HENRY FAIRFIELD OSBORN ON THE TITANOTHERES.

in physics when it is in a field in which he has only a vague understanding. Therefore the preferred exhibit is directed to an intellectual age of about fourteen.

There are many elements entering into a general evaluation of an exhibit. The most important is visitor participation. If the set-up is so designed that the visitor can push a button, turn a crank or otherwise make a demonstration for himself, the maximum interest is most certain. Next in interest are those exhibits in which a demonstrator causes a sequence of performance. But the cleverness of the demonstrator in correlating his speech and action is quite as much a factor as it is in any stage performance. Third in order of merit are those exhibits automatically in motion and showing some progression in illustrating a fact or a theory. Live mice being chased around a small stage by a disagreeable light or by electrical shocking devices of different frequencies from different parts of the cage would come in this same category. Static exhibits in glass cases are at about the worst disadvantage and only one degree better than wall posters, charts and tabular material.

However, it must be admitted that in a collection of exhibits there is an indefinable value in the correlation of the exhibits, and the composite eye impression has a value which is just as im-

portant, even if indefinable, as the eye impression that one gets upon entering a home, a department store or a railway station.

At the Cleveland meeting there were, besides the commercial exhibits, presentations in the diverse fields of science from the American Museum of Natural History, the Carnegie Institution of Washington, the U. S. Bureau of Standards, the Crile Laboratories, University of Chicago, the Bell Telephone Laboratories, Electrical Research Products Company, the Boyce-Thompson Institute, Leeds and Northrup Company in cooperation with the Museum of Science and Industry of New York, the Acoustics Research Laboratory of the American Steel and Wire Company, Blodgett Memorial Hospital, the Cleveland Clinic, Westinghouse Electric and Manufacturing Company, Dr. C. W. Kanolt.

These were all good when judged by the sustained interest of the crowds and by the interest of the news services. I am informed that the newspapers gave almost as much space to the exhibits as they did to the remarkable new achievements presented to the world for the first time in the form of papers.

It should be added that commercial scientific establishments are of the utmost importance to scientific advance. Schuster, in one of his books, has said that the advance in science seems to have followed the advance in the instruments of precision that are made for the use of the scientists. The public does not know the whole story of merit in the advance of science unless it also knows of the work that is being done by these commercial scientific establishments. It was observed at Cleveland that there was very great interest on the part of the general public, as well as by the visiting scientists, in the commercial exhibits. In fact, this intellectual curiosity on the part of the public seemed at times to be embarrassing to the men with this type of exhibits.

At future meetings a special effort should be made to enhance further the mutual profit to the commercial exhibits, as well as to the general public. Moreover, the commercial establishments will find in each large city a great many potential amateurs among the public who may develop into at least quasi-scientists and users of scientific equipment.

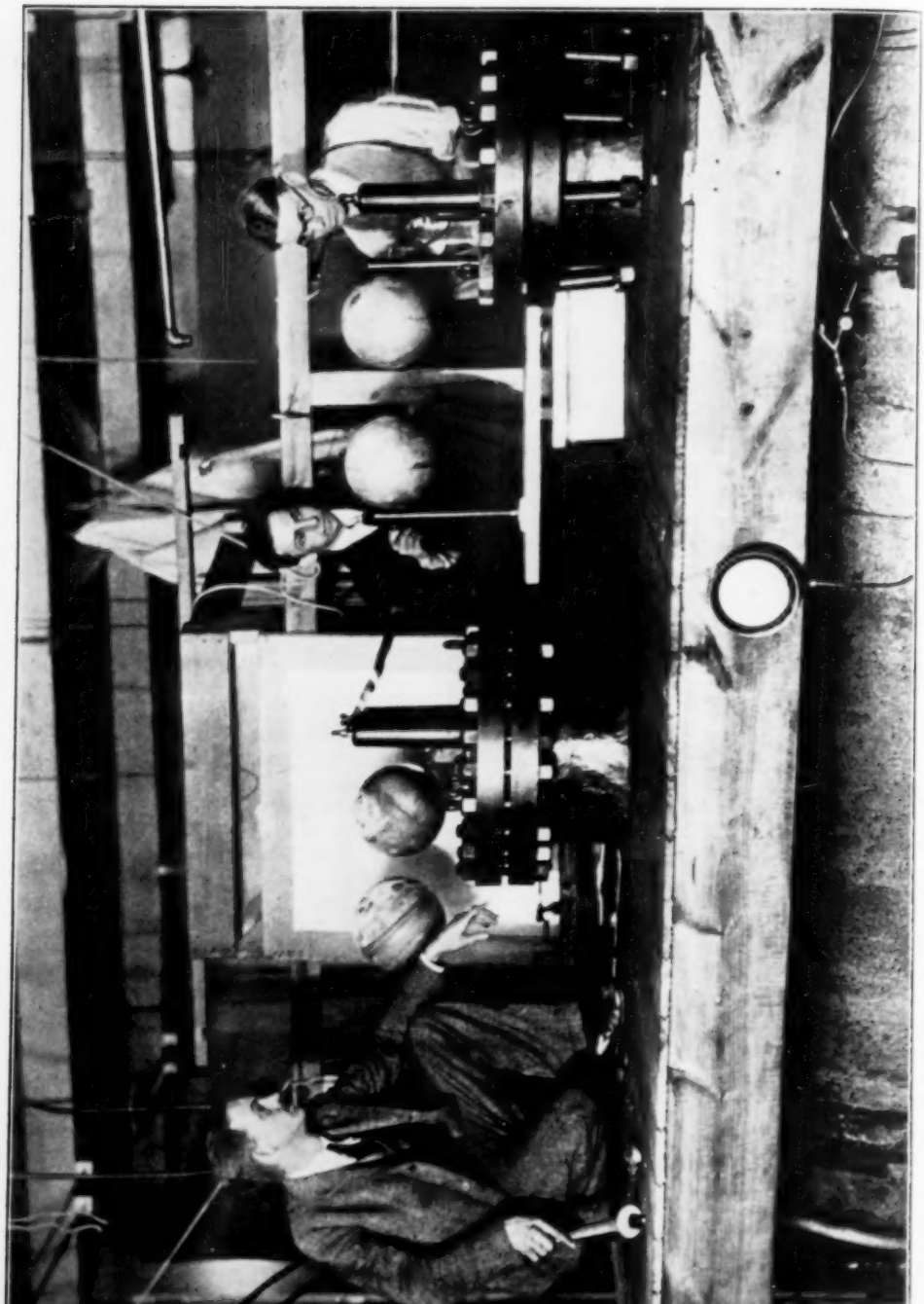
I would like to close with a quotation from a talk given by Sir William Bragg at a recent luncheon of the New York Museum of Science and Industry:

> We are linked together in one great endeavor to make the presentation of knowledge understood by the people and useful to them. That is the elemental feature. . . . As time grows and the horizon widens, we see that the first views of what science does are greater now. We are all committed to the attempt to try to bring it to the service of mankind. It is a great enterprise and we only see dimly now what can be done, but we do hope to do much. In the attempt to explore the wonders of the world, to add beauty where people did not see beauty before, we are doing something for the service of mankind.

F. C. BROWN

THE EIGHTH AWARD OF THE AMERICAN ASSOCIATION PRIZE

THE eighth award of the American Association for the Advancement of Science prize of one thousand dollars was made at Cleveland to Drs. M. A. Tuve, L. R. Hafstad and O. Dahl, of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, who were joint authors of a paper entitled "Experiments with High Voltage Tubes" presented at the Cleveland meeting. This prize is awarded annually to the author of a notable contribution to the advancement of science given at the association meetings.



THE HIGH VOLTAGE TUBE AT THE CARNEGIE INSTITUTION OF WASHINGTON

DR. M. A. TUVE (LEFT) AND DR. L. R. HAFSTAD (RIGHT) AND DR. O. DAHL (NOT SHOWN) WERE THE RECIPIENTS OF THE AMERICAN ASSOCIATION PRIZE

A summary of the high-voltage work as given by Dr. Tuve in his presentation of the paper at Cleveland is as follows:

(1) Using the high voltages produced by ordinary Tesla coils immersed in oil we have operated sectional high-voltage tubes to approximately 2,000,000 volts.

(2) We have made measurements of the deflections in a calibrated magnetic field of the beta-rays produced by these tubes. The maximum Hp values (the numerical measure of the deflections of the electrons in the magnetic field—Ed.) measured for these beta-rays correspond in equivalent voltage to the peak voltages applied to the tube, as measured by the capacity potentiometer. This constitutes a completely independent verification of our voltage measurements.

(3) Since most of the beta- and gamma-rays from radium have voltage equivalents under 1,000,000 volts and nearly all lie under 2,000,000 volts we have artificially produced beta- and gamma-rays practically covering the radium spectrum.

(4) We have measured the gamma-rays from the tubes through one, two and three inches of lead using a Geiger Müeller tube-counter. At 1,300,000 volts peak the absorption coefficient of the gamma-rays from the tube after filtering through one inch of lead is practically the same as the absorption coefficient of the gamma-rays from radium measured on the same instrument with the same filtering.

The above statement, despite a few technical phrases, gives a reasonably understandable account of the work for which the award was made. In essence it is simply that two of the three types of rays emitted by radium, the beta-rays or very high-speed electrons, and the gamma-rays, or very penetrating x-rays, have been produced artificially in the laboratory.

The work which was reported at the Cleveland meeting had been presented two weeks previously in Washington at the annual public exhibit of research activities of the Carnegie Institution of Washington.

In the exhibit the high-voltage tube and associated apparatus with which the artificial beta-rays were produced and measured was shown, together with typical examples of the beta-ray records. Records of the gamma-rays from the tube, obtained after penetrating one, two and three inches of lead, were given, and comparison records of the beta- and gamma-rays from radium were shown to illustrate the fact that the artificial rays produced by the high-voltage tubes covered practically the complete range or spectrum of the corresponding rays from radium. One of the interesting technical features of the work was the method of "heat working" of the pyrex glass from which the tubes are constructed.

Considerable public interest has arisen in the possibility of using the gamma-rays from such tubes for the treatment of cancer, since the rays from the tubes are identical with those used in the therapeutic applications of radium. The equipment as used in these experiments produces an intensity of radiation equivalent to enormous quantities of radium but only for extremely short periods of time, the operation of the tube being intermittent. Due to the limitations of small-sized electrical equipment and to the lack of necessity for large intensities of radiation for the physical measurements, as well as the personal risk to the experimenters themselves from heavy exposures to the rays, no particular effort has been made to increase the total intensity of the radiation. This would mean simply increasing the fraction of the time which the high voltage is applied to the tube during each second of operation, thereby increasing the time-average of the intensity of the radiation from the tube. If large intensities of gamma-rays, comparable to very large amounts of radium, are desirable for medical purposes, it is, so far as can be foreseen by workers in this field, chiefly a matter of the provision of the equipment which would be required. The present equipment at the Carnegie Institution laboratory, of small power but giving a very high voltage, promises usefulness in directions related to atomic physics rather than to medicine.

DR. HANS FISCHER

THE AWARD OF THE NOBEL PRIZE IN MEDICINE TO DR. HANS FISCHER

THE question which arises in the mind of the general public—and the general public includes everybody except closely related specialists—when a scientist is extolled by the award of a Nobel Prize is, What benefit will mankind derive from the work which is thus singled out? The practical benefit, however, is not the standard of rating of scientific attainment unless the term includes the satisfaction of the curiosities of the human mind. The standard for rating a scientific work is based on the aims of the given branch of science. Chemistry is a broad science composed of many branches, each having its own tasks, each with its own history. The branch of chemistry to which the contributions of Hans Fischer belong is named "Organic Chemistry." Its aim is the study of the architecture of substances of plant or animal origin. It is one of the oldest fields of human endeavor, yet it won the rank of a rational science only in the second half of the last century when it evolved its own theory and its own aims. Until that time the contributions of organic chemistry were of an empirical character. The great contribution of organic chemistry of the nineteenth century was the evolution of theory. If the Nobel Prize had then existed, it should have been awarded to Wöhler, Dumas, Laurent and Gerhardt, Kolbe and Frankland, Cooper and Kekulé—not for work on the molecular architecture but for devising ways by which the architecture became discoverable. The possession of the theory then made it possible to proceed with the original aim of organic chemistry. Indeed, so true is the theory that for nearly three quarters of a century it led to one discovery after another which were crowned with Nobel prizes. Suffice it to mention the names of Emil Fischer in connection with the molecular structure of sugars and of uric acid; v. Beyer with the structure of indigo; Willstätter with the structure of chlorophyll; Wieland with the structure of bile acids; Windaus with the structure of cholesterol. To this list now is added the name of Hans Fischer in connection with the structure of hemoglobin.

The history of hemoglobin is a very long one. The substance was discovered in 1849 by a biologist, Leydig, who observed red crystals in venous blood examined microscopically. Later observers who prepared the crystals, not in microscopic but in considerable quantities, were sceptical as to the origin of the color and were inclined to attribute the color to a contaminating substance. In 1862 Hoppe-Seyler, having resorted to the spectroscope for the analysis of the substance, established its individuality and introduced the name "hemalglobin." Hoppe-Seyler also recognized that hemoglobin was a complex protein which could be decomposed into a colorless protein and into a component responsible for the color. In fact, the colored component had been known since 1853 when Teichmann described the blood crystals which are nothing else but the colored component of hemoglobin combined with chlorine. The function of hemoglobin in the organism is to transport to the tissues the oxygen required by them for their respiration; in other words, to permit them to develop the energy required for their respective functions. Hemoglobin, or rather its colored component, hematin, constantly undergoes decomposition and its supply constantly needs replenishing. It is calculated that every two and a half months the total hematin supply of the human organism is entirely renewed. The place of destruction of hematin is in the liver and the useless product of its decomposition is the so-called bile pigment, bilirubine. The existence of a chemical relationship

between the two substances was long known to physiologists, but the exact nature of the relationship was in need of explanation. In course of time it was found that substances related to hematin have a wide distribution in living cells of animal and plant origin and also in non-cellular tissues of all forms of life. The nearest relative of hematin is the chlorophyll present in all green plants.

Thus it is seen that the problem of the structure of hematin and related substances had engaged the interest of biologists and of chemists for a very long time and, indeed, to Willstätter the Nobel Prize had already been awarded for his contribution to the chemistry of chlorophyll and Willstätter already had suggested a theory of the structure of hematin. Kuster, in 1912, advanced a theory of structure of hematin which is not much different from the one evolved by Hans Fischer. The question here again arises as to the unusual merit of the work of the latter. The answer is found in the writings of Hans Fischer himself. The colored component of hemoglobin as first crystallized has the composition $C_{34}H_{32}N_4O_4F_3Cl$, hence it consists of 76 atoms. A theory of structure of the substance must represent such an arrangement of the atoms with respect to each other which expresses all its properties and all its transformations. Often, however, several closely related arrangements may express sufficiently well the properties of a substance and the selection of the true may present great difficulties. In discussing his own speculations as well as those of other workers, Hans Fischer repeatedly emphasized that the truth of the theory can be demonstrated only by synthesis and such a proof has finally been furnished by himself. To realize the magnitude of the achievement it is necessary to understand that the porphyrine (the iron and chlorine free part) of hemin consists of four pyrrolnuclei (not all of identical structure) each consisting of a ring structure containing 4 carbon atoms and 1 nitrogen. These four units are combined by links of a carbon atom into a larger ring containing in all 20 carbon atoms. The remainder of the carbon atoms, 14 in number, have to be distributed as side chains of the four pyrrolnuclei. Information as to this distribution was obtained to some extent by the process of cleavage which led to the formation of the hemapyrrol bases and hemapyrrol acids. From the theory of the structure of these fragments by speculation, the molecule of hemin has been reconstructed. Hans Fischer, however, reconstructed the molecule of hemin experimentally step by step, first contributing much to the knowledge of the pyrrolderivates, then combining two pyrrolnuclei through a carbon link into a single complex, and, furthermore, linking these complexes into such as contain the skeleton of the porphyrines consisting of a system of four pyrrolnuclei as it occurs in hemin. Finally, he succeeded in producing in the laboratory hemin as it occurs in nature.

Hans Fischer began his work in 1911 with a study of bilirubine, the bile pigment, and its relationship to urobiline, the urine pigment. The work was begun at the suggestion of Professor Friedrich Müller, the great clinician, whose assistant Fischer then was. One could scarcely have predicted, at that time, that this modest beginning would lead to the elucidation of an extensive class of pigments occurring in all forms of life with a promise of further discoveries. It must be emphasized that ingenuity of mind and virtuosity of technique alone were not sufficient to accomplish the work of Fischer. It required, in addition, the gift of leadership and organization.

P. A. Levene